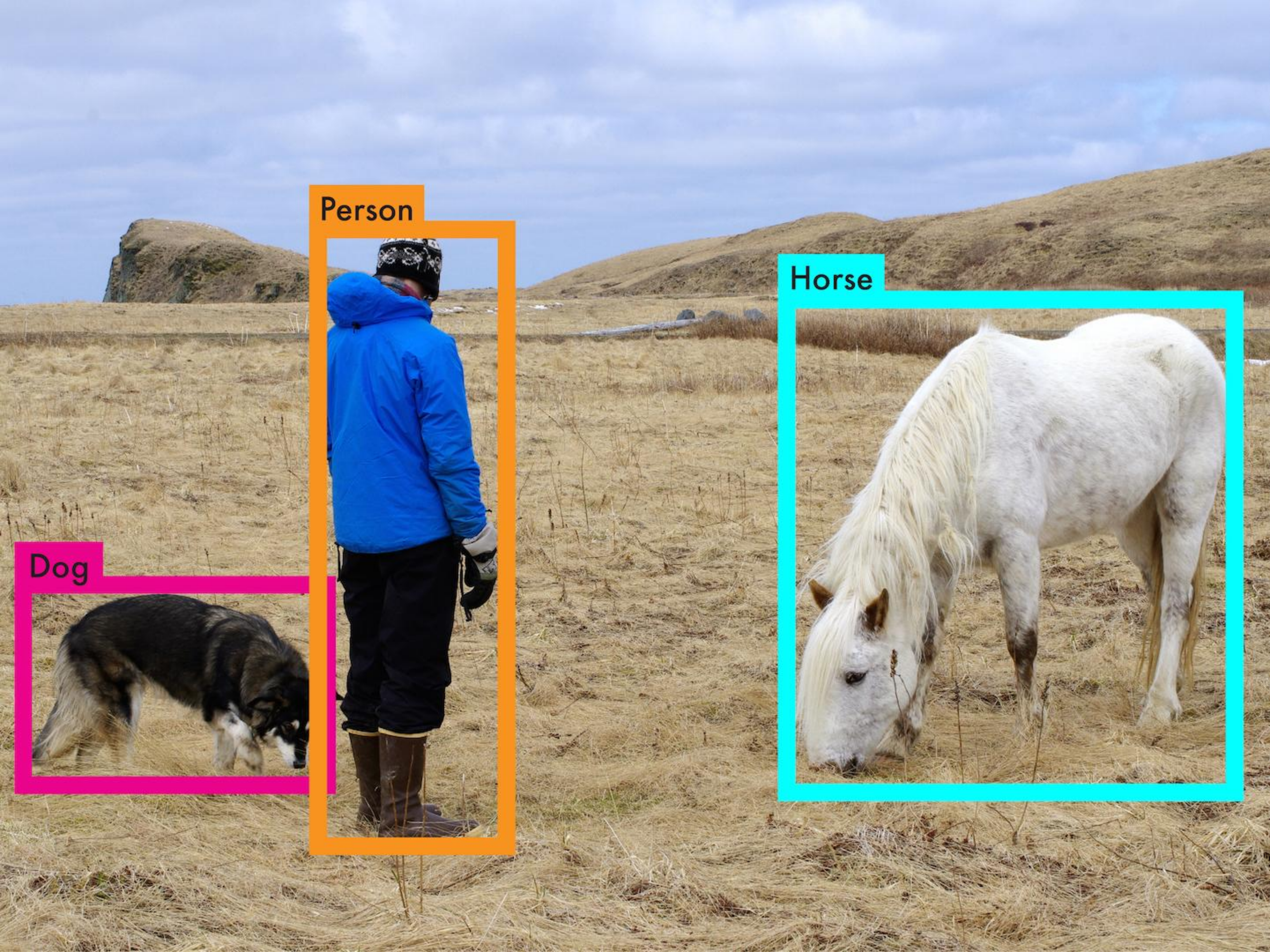

JOSEPH REDMON
ROSS GIRSHICK
SANTOSH DIVVALA
ALI FARHADI
Dog
MOST ACCURATE REAL-TIME DETECTOR 2016
FASTEST OBJECT DETECTOR IN THE LITERATURE 2016
"YOU ONLY LOOK ONCE"
REAL-TIME DETECTION


Person
Horse
Dog

Accurate object detection is slow!

	Pascal 2007 mAP	Speed	
DPM v5	33.7	.07 FPS	14 s/img

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⅓ Mile, 1760 feet

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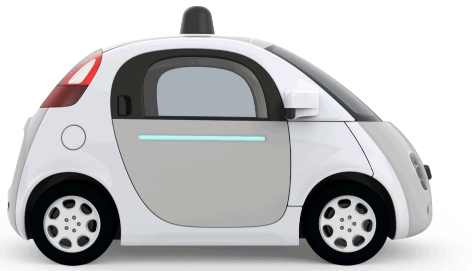

176 feet

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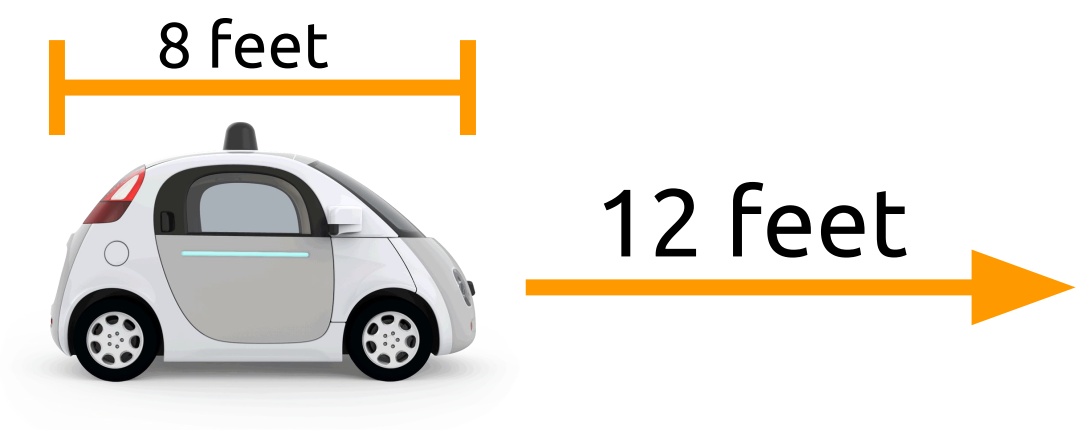
Faster R-CNN	73.2	7 FPS	140 ms/img



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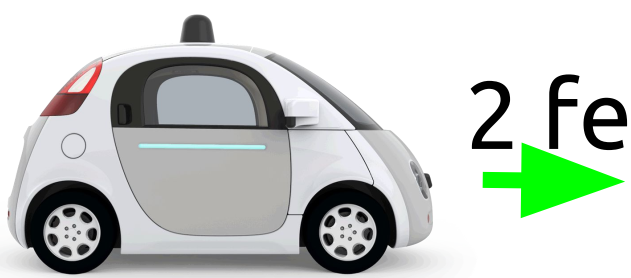
YOLO	63.4	45 FPS	22 ms/img



2 feet

Accurate object detection is slow!

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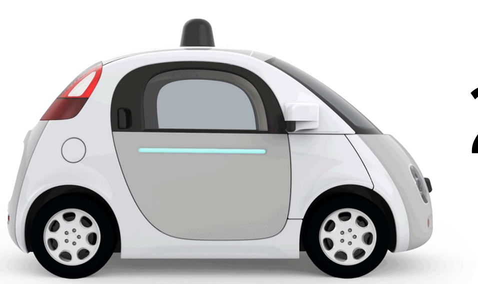
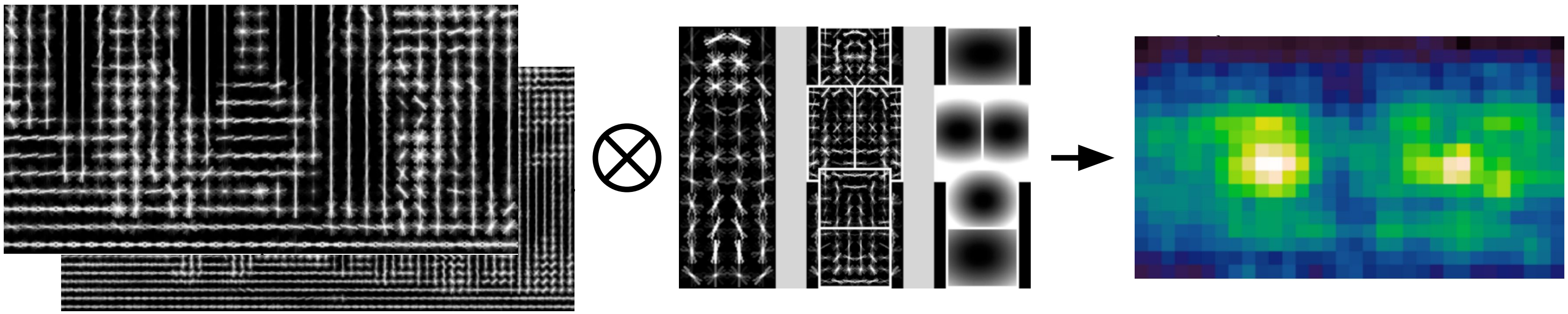
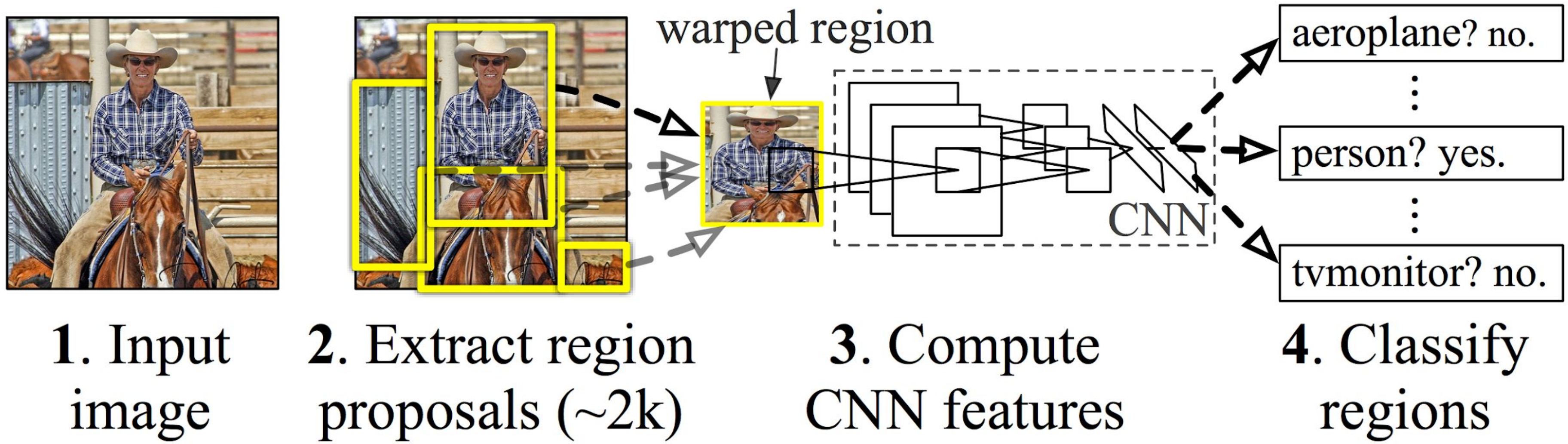


2 feet

DPM: *Deformable Part Models*

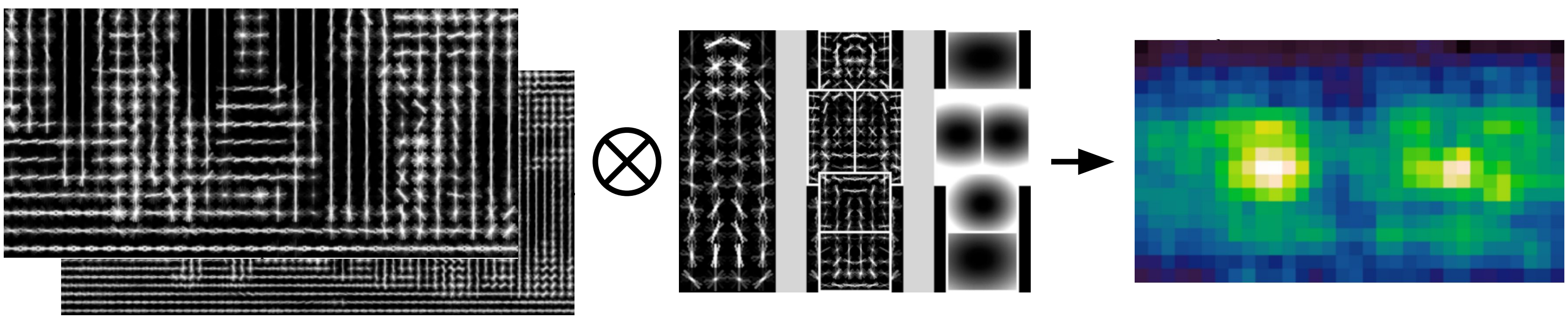


R-CNN: *Regions with CNN features*

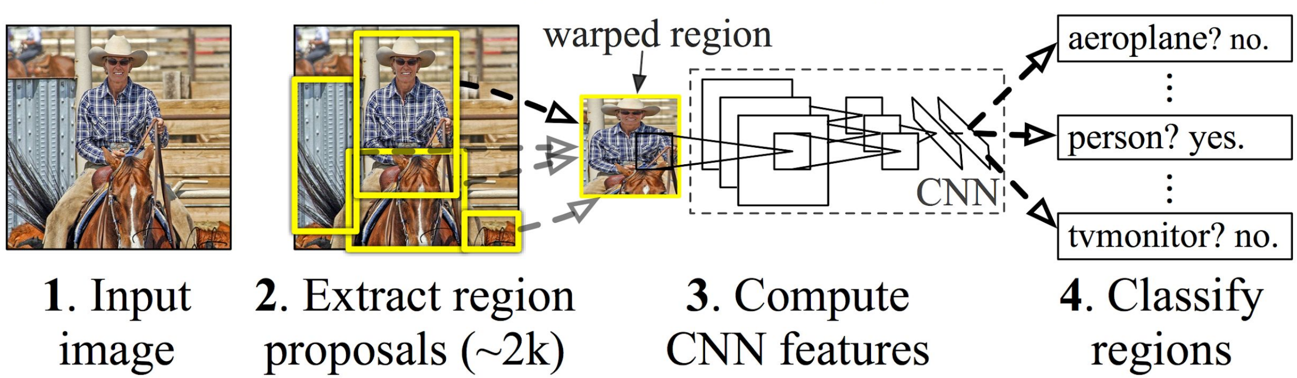


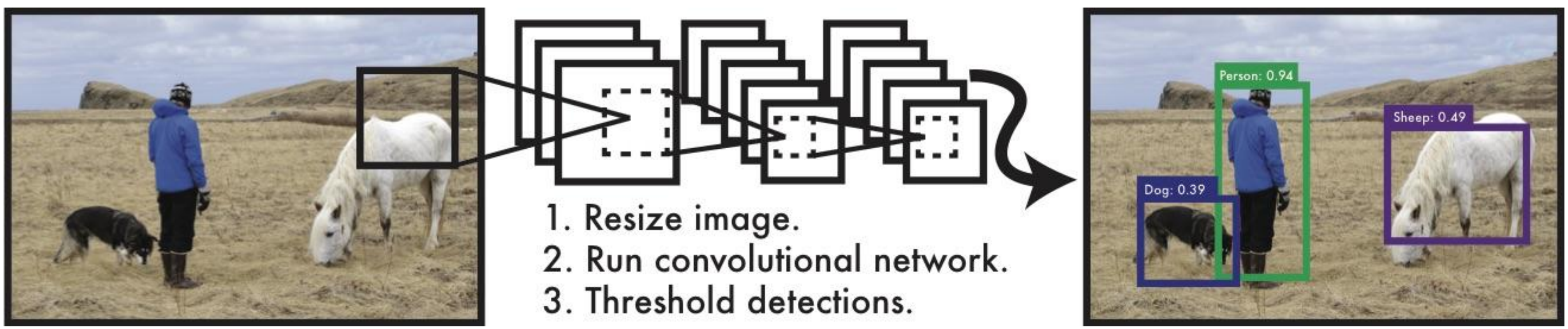
Sliding window, DPM, R-CNN all train region-based classifiers to perform detection

DPM: ***Deformable Part Models***

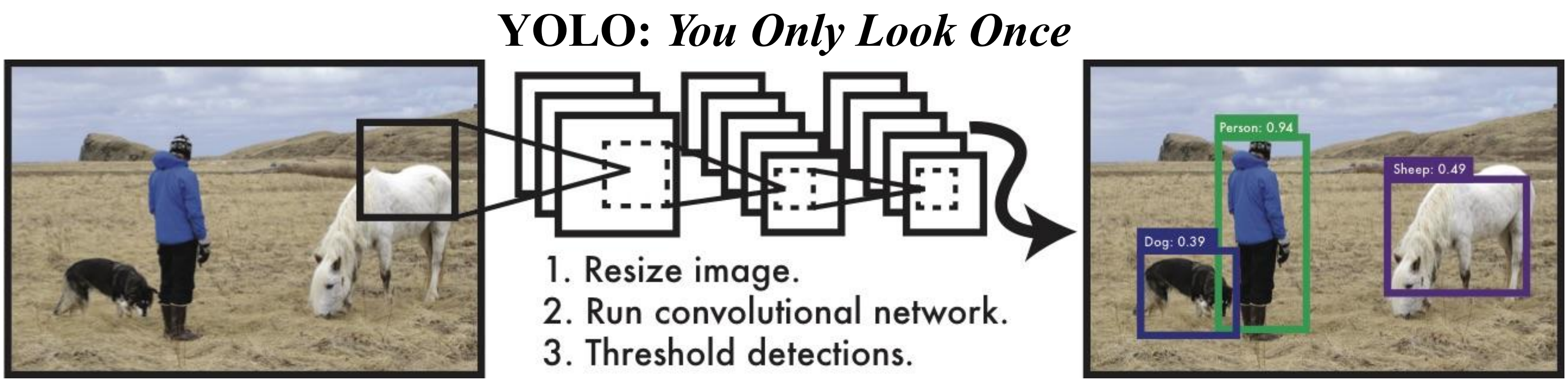


R-CNN: ***Regions with CNN features***

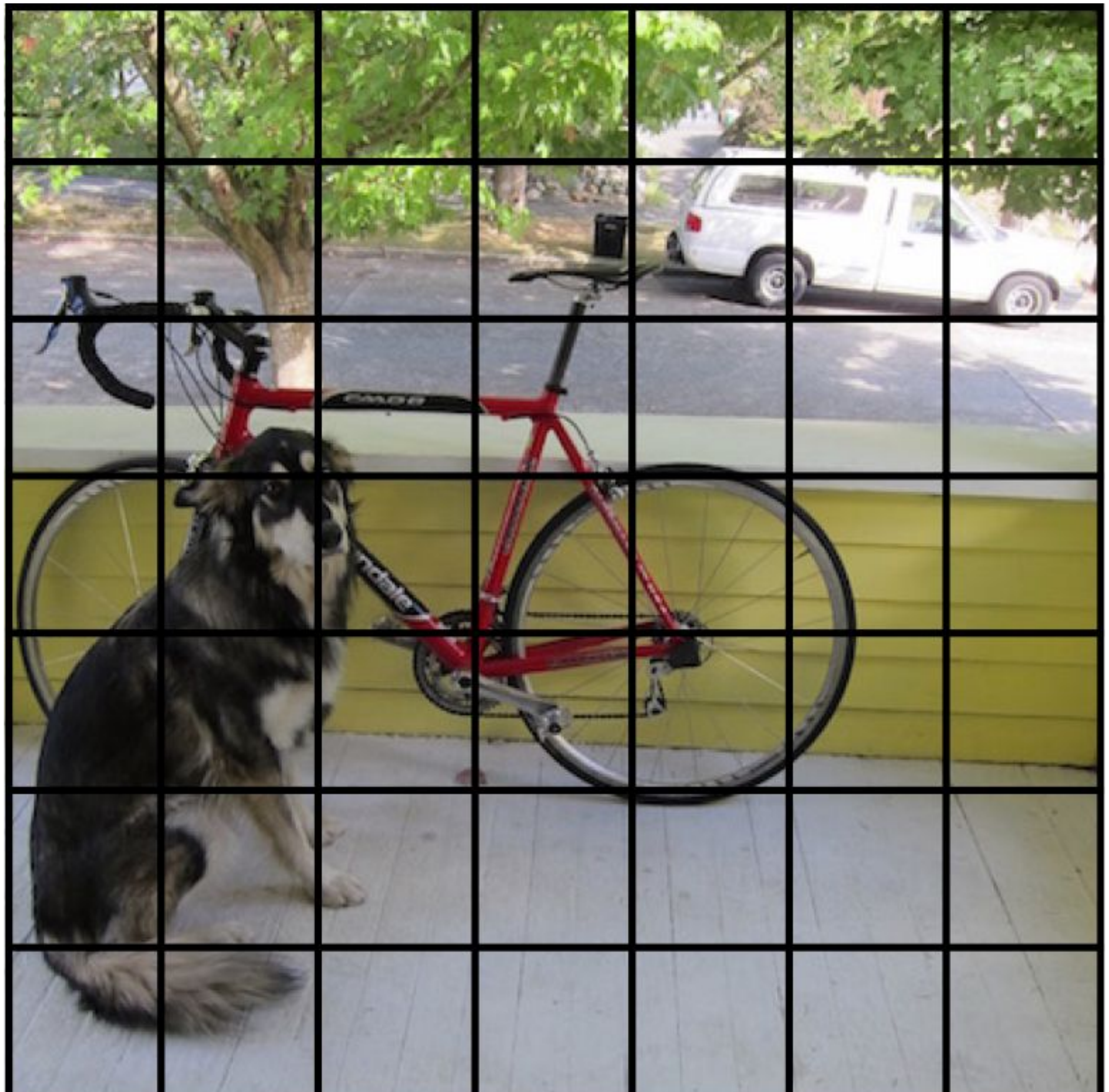



1. Resize image.
2. Run convolutional network.
3. Threshold detections.
Person: 0.94
Sheep: 0.49
Dog: 0.39

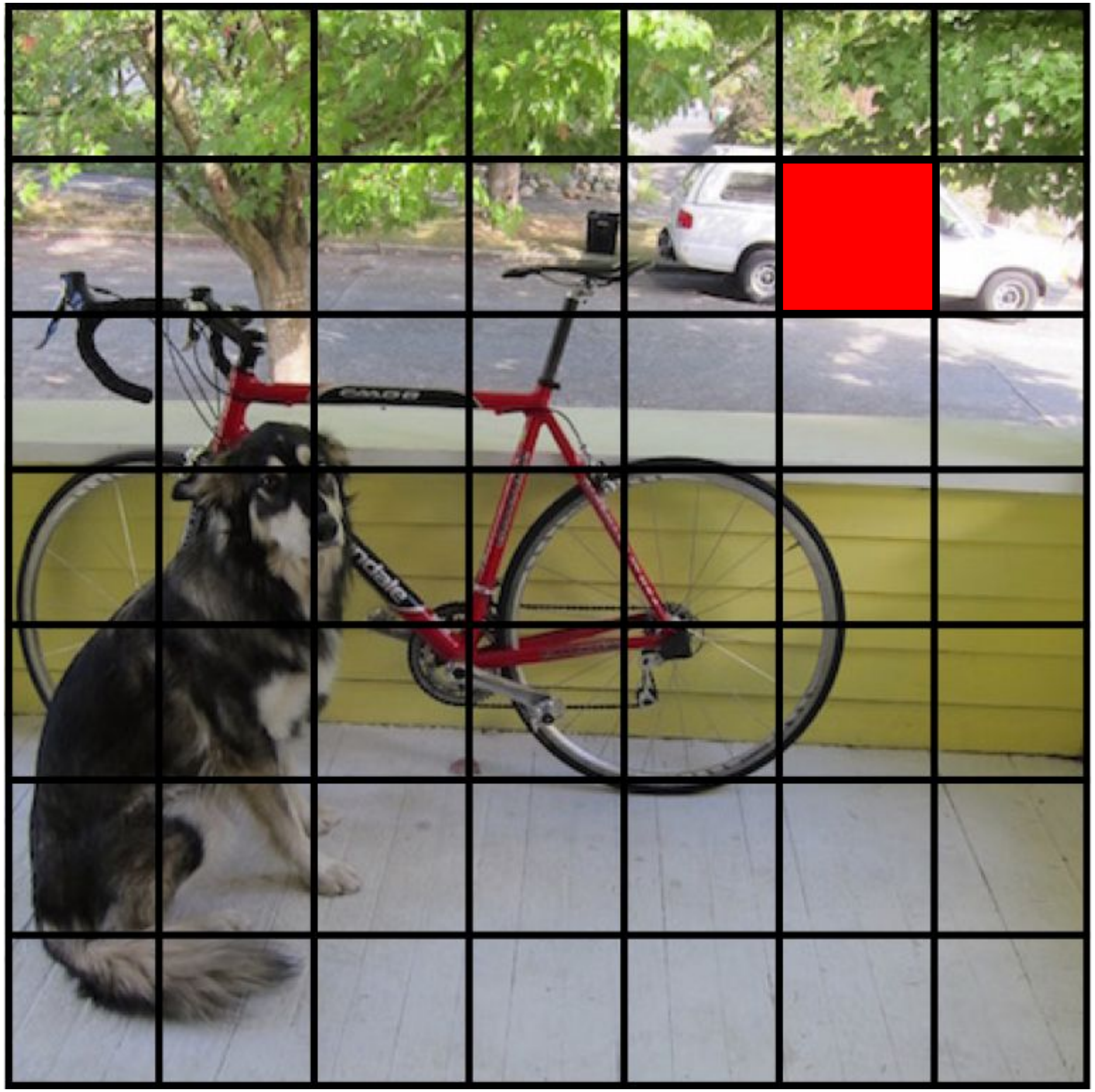
With YOLO, you only look once at an image to perform detection



We split the image into a grid



Each cell predicts boxes and confidences: P(Object)



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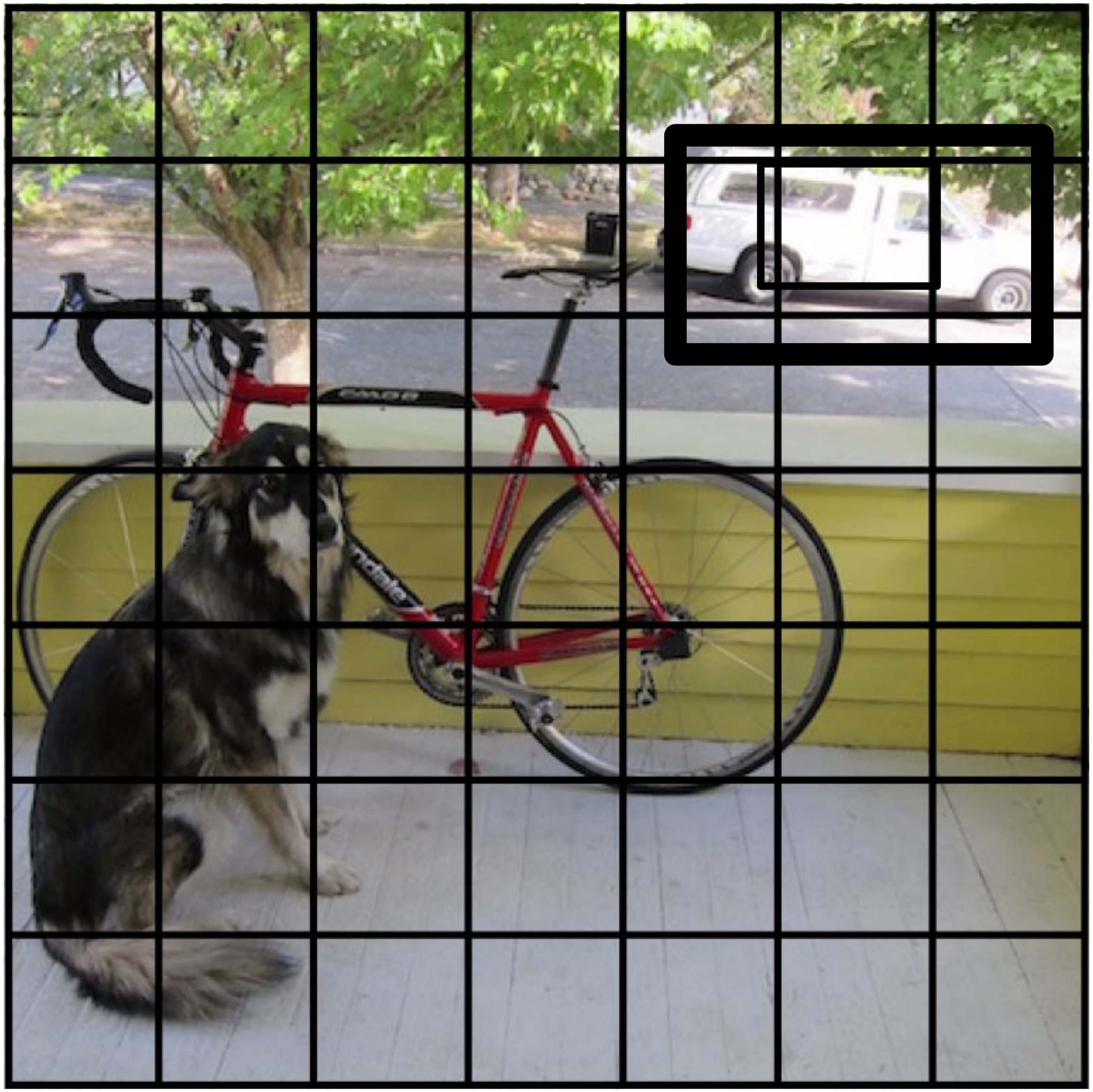

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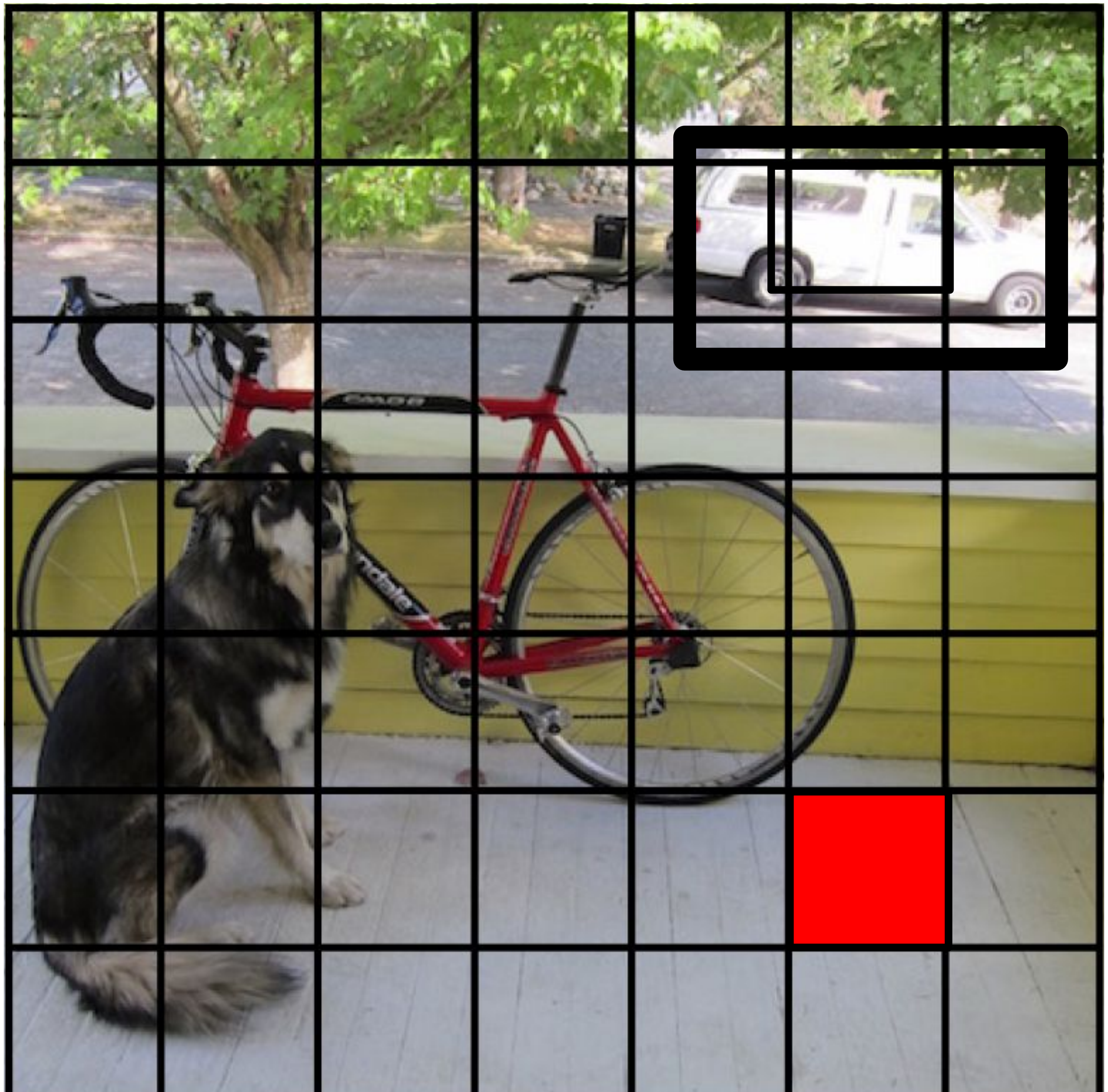

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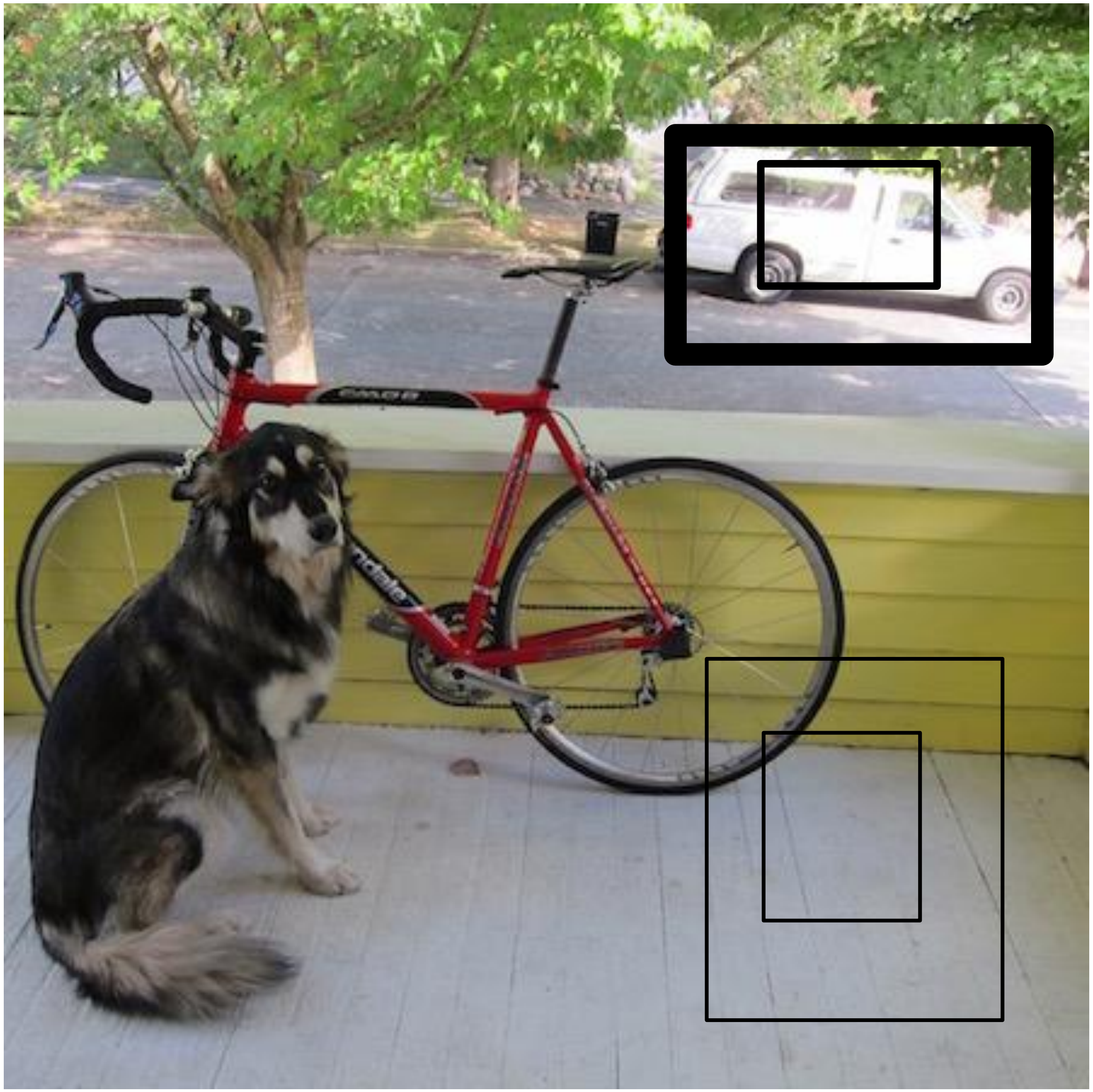
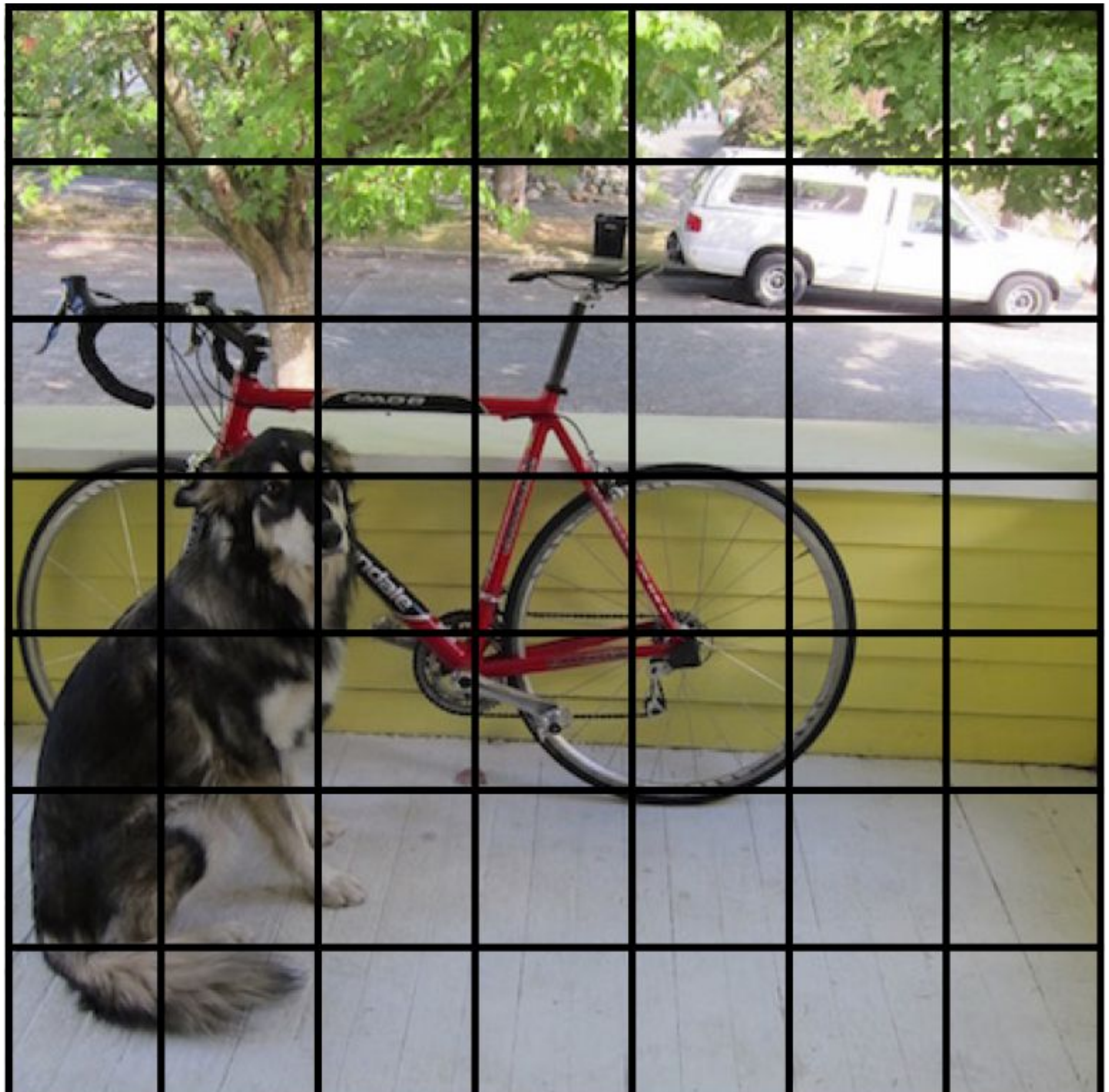


Each cell predicts boxes and confidences: P(Object)

Each cell also predicts a class probability.



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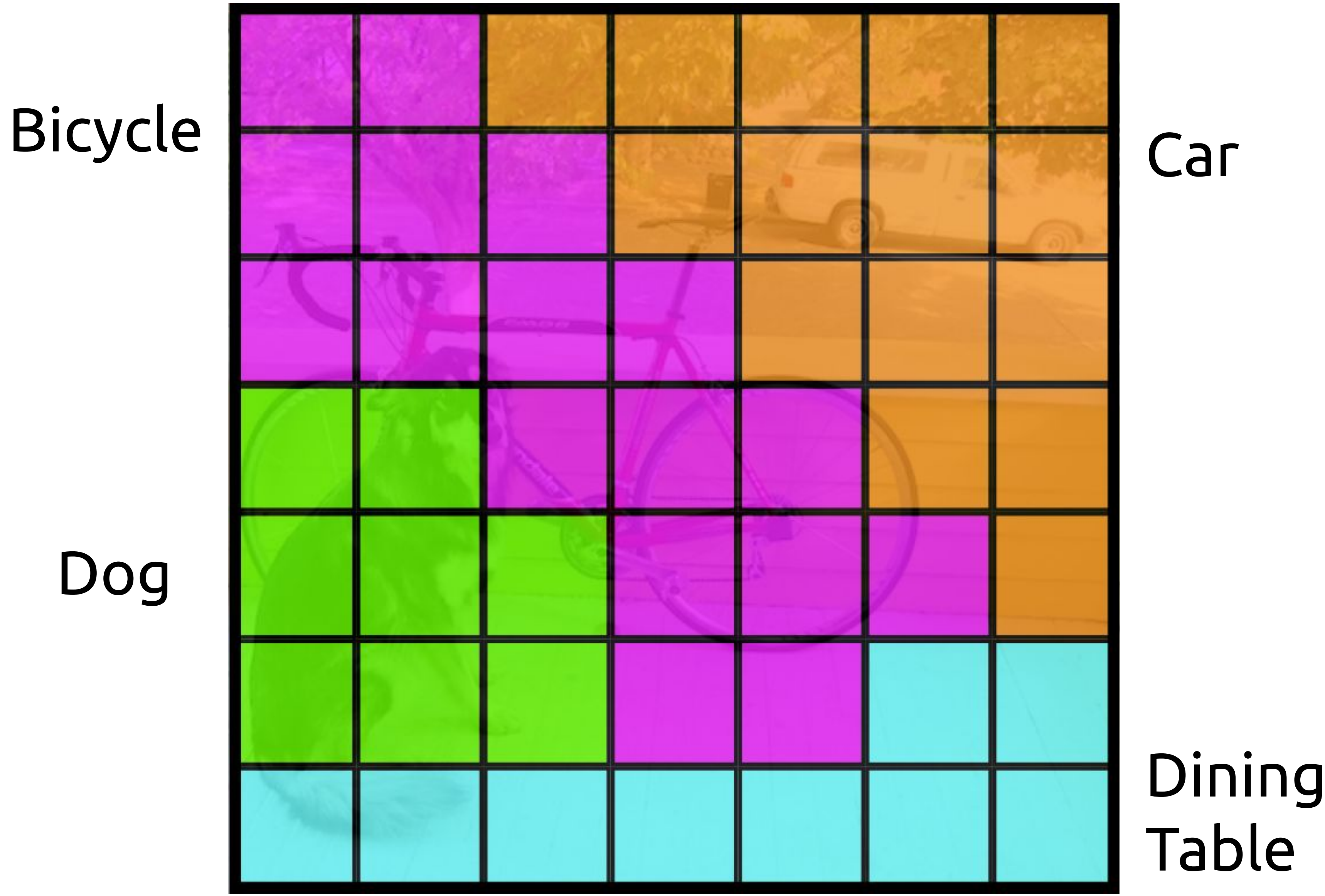
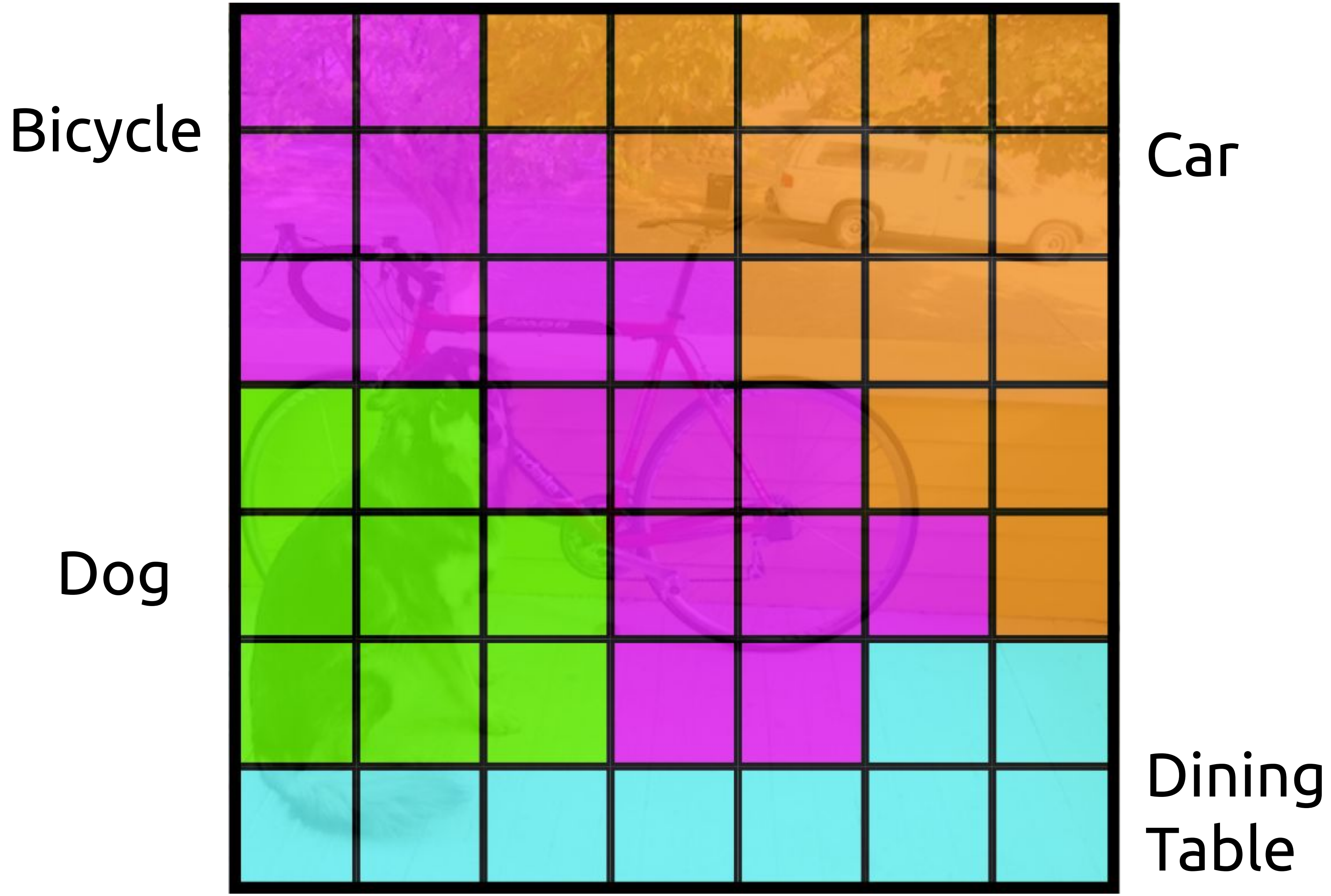
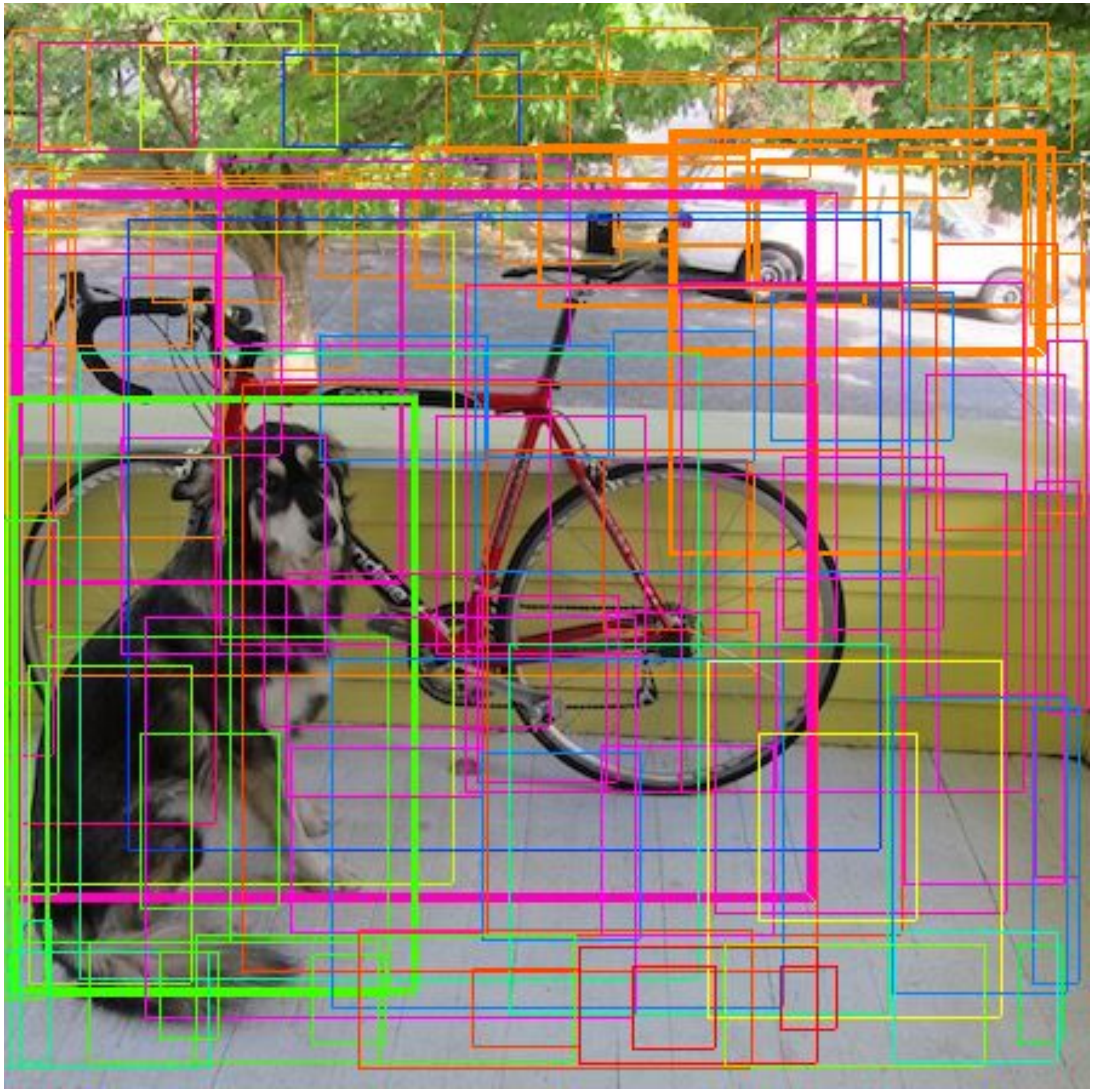


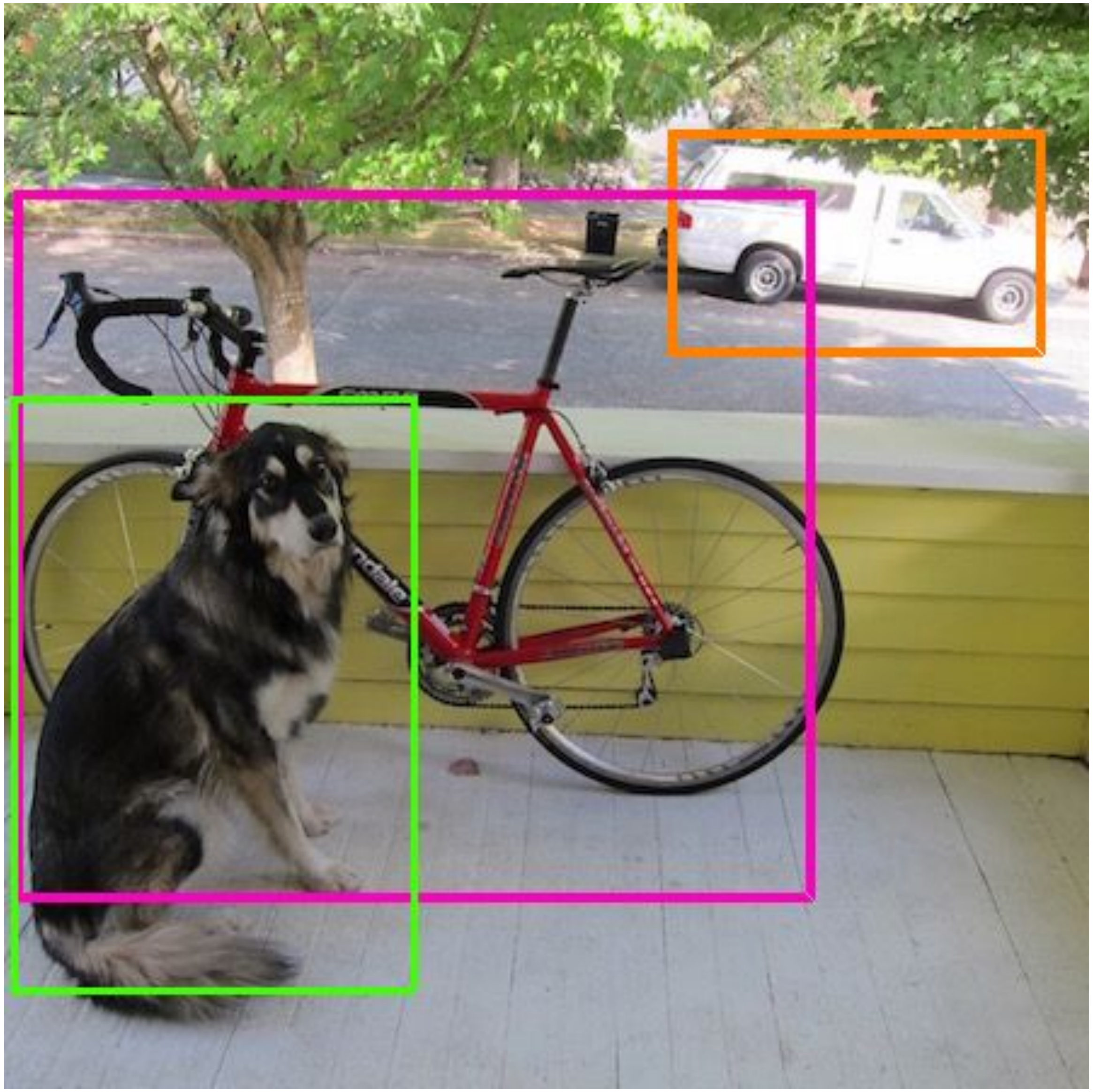
Conditioned on object: P(Car | Object)



Then we combine the box and class predictions.



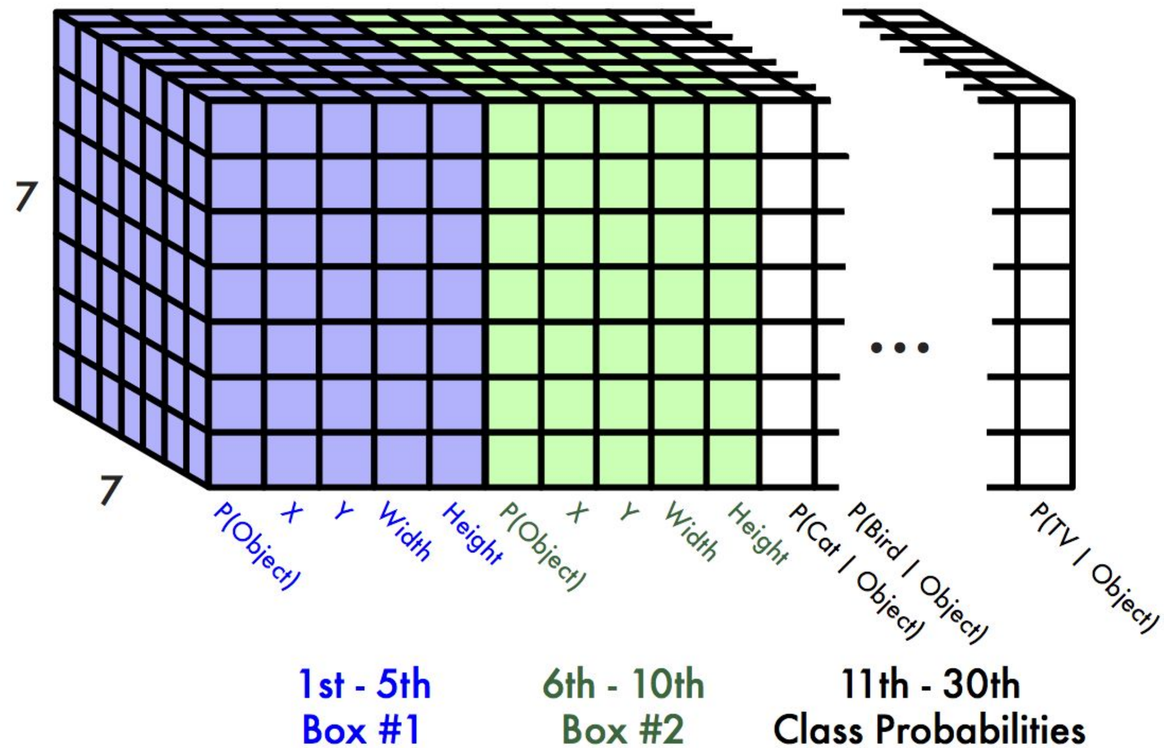
Finally we do NMS and threshold detections



This parameterization fixes the output size

Each cell predicts:

- For each bounding box:
  - 4 coordinates (x, y, w, h)
  - 1 confidence value
- Some number of class probabilities

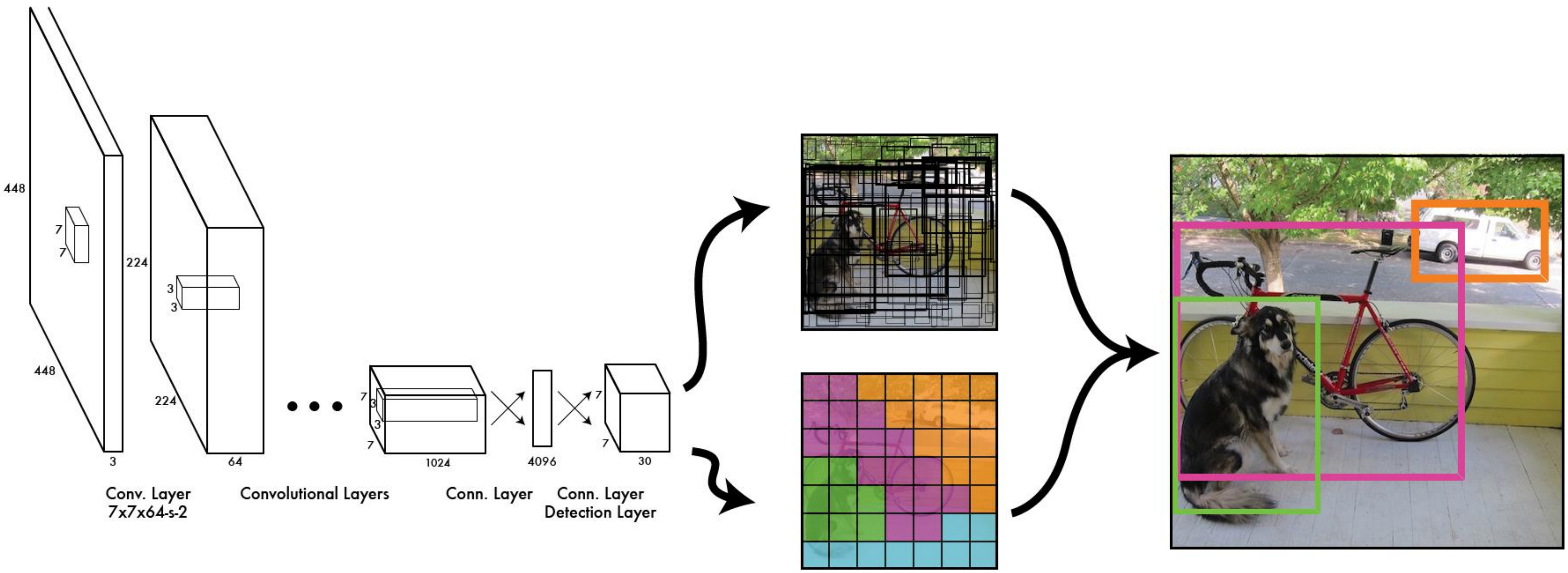


For Pascal VOC:

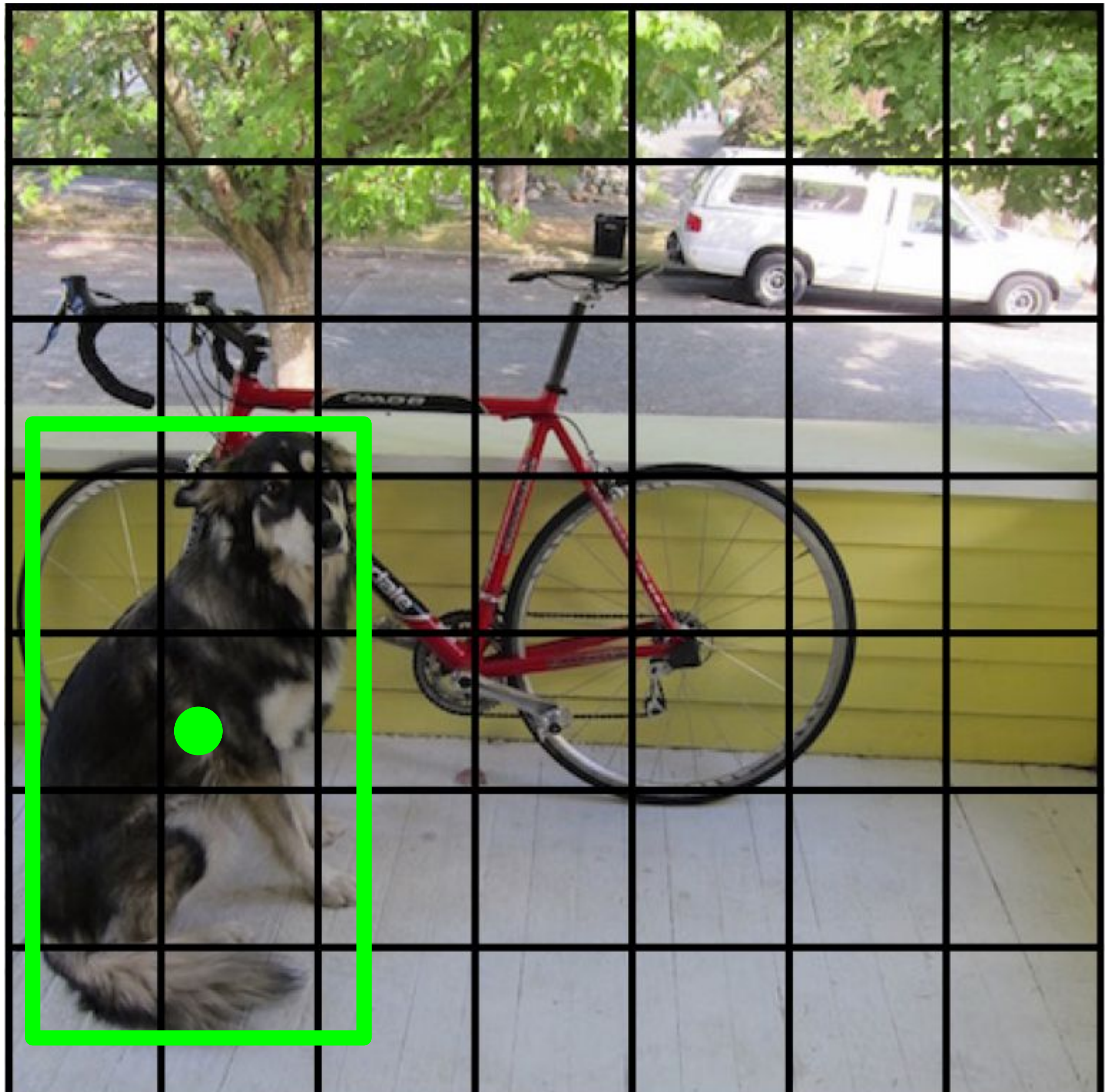
- 7x7 grid
- 2 bounding boxes / cell
- 20 classes

7 x 7 x (2 x 5 + 20) = 7 x 7 x 30 tensor = **1470 outputs**

Thus we can train one neural network to be a whole detection pipeline



During training, match example to the right cell



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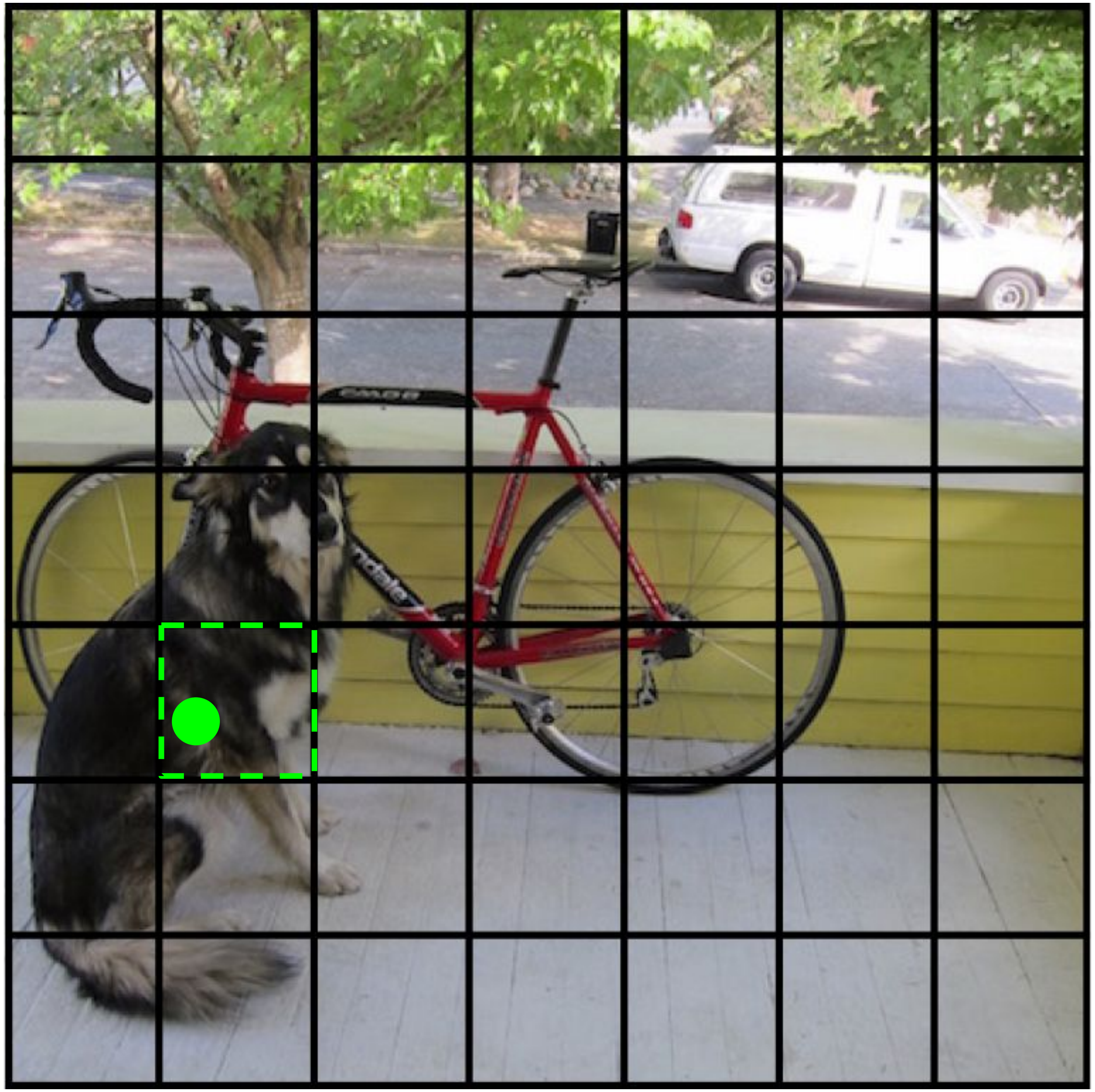
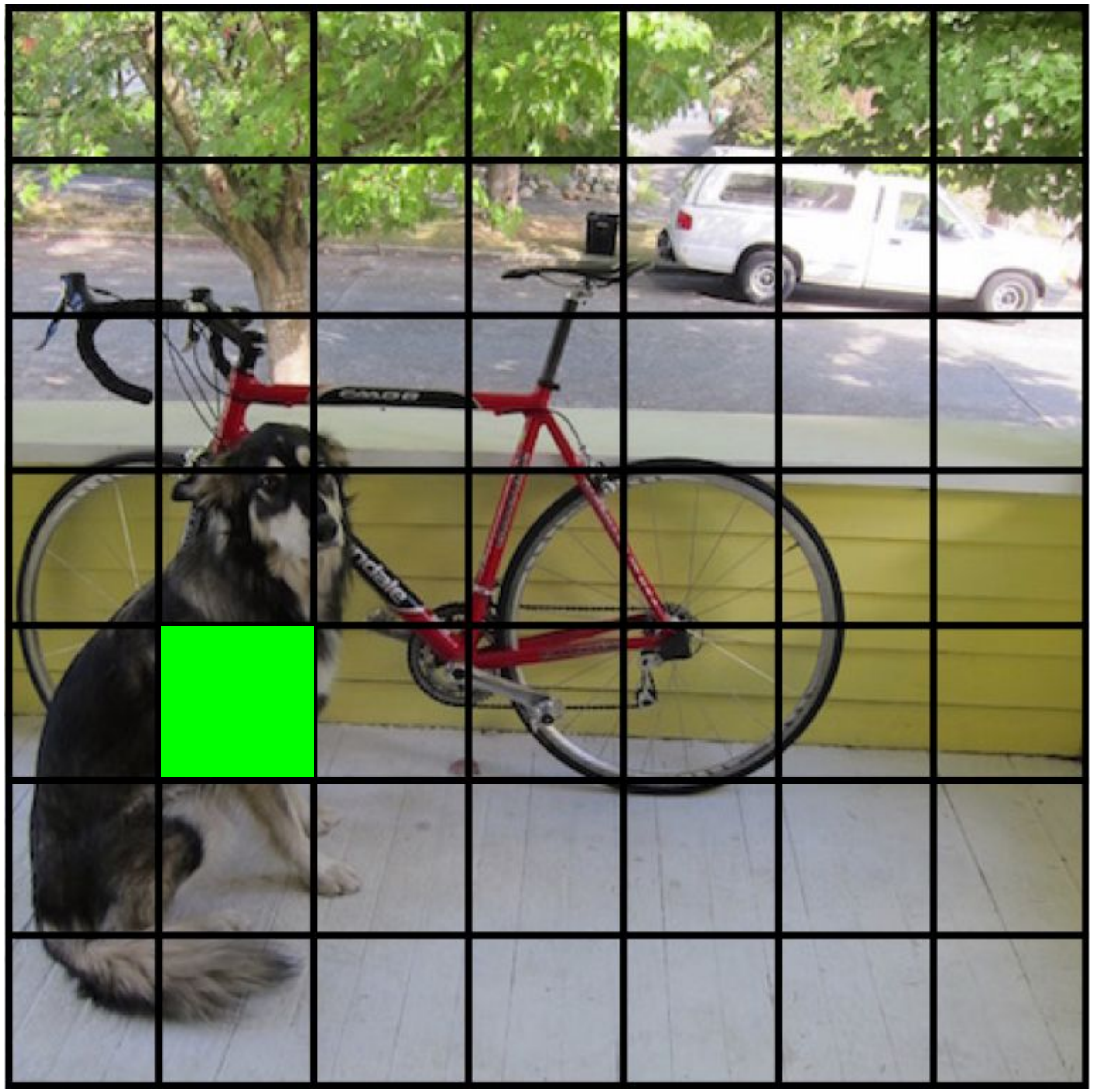
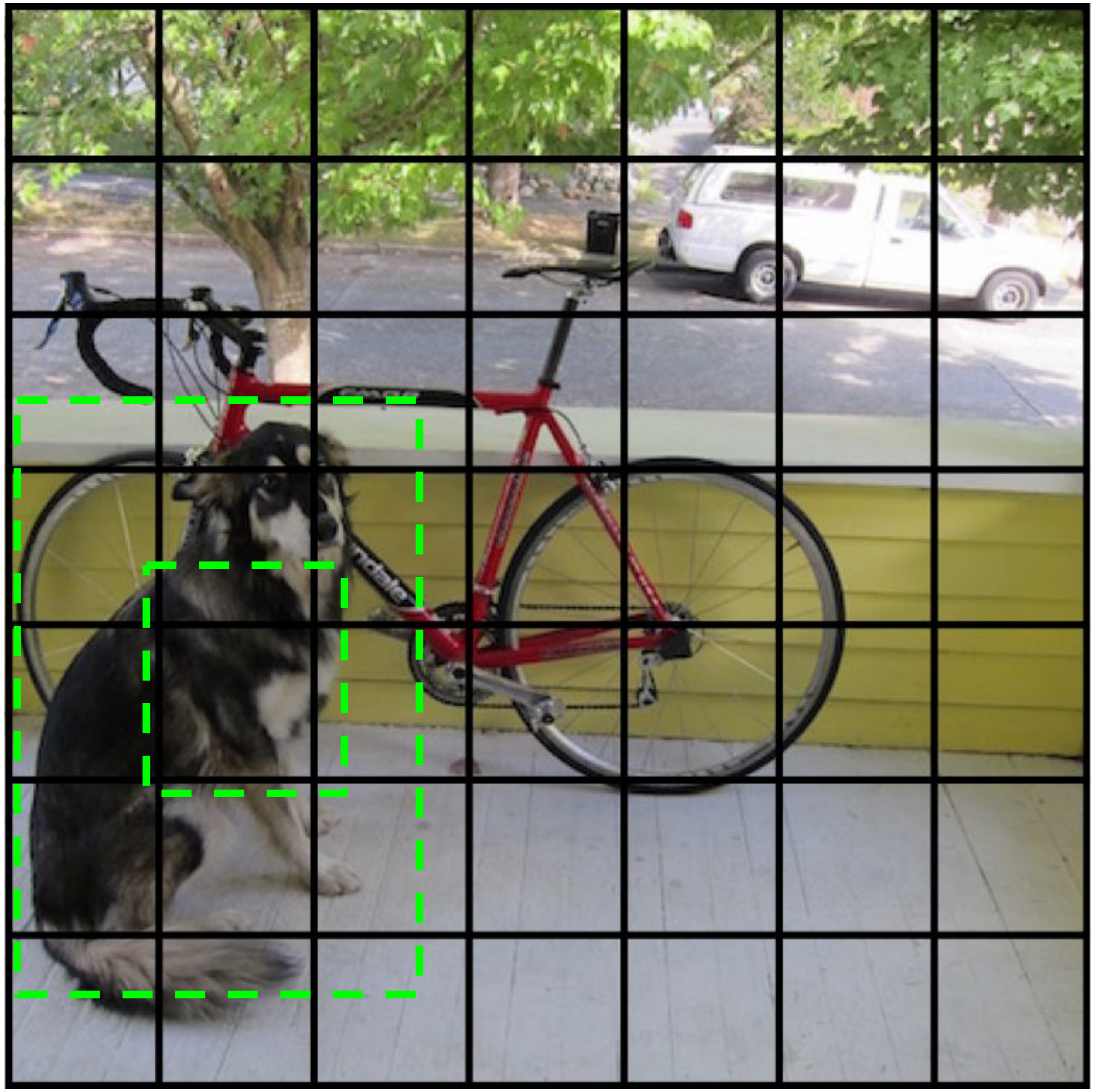


Adjust that cell's class prediction

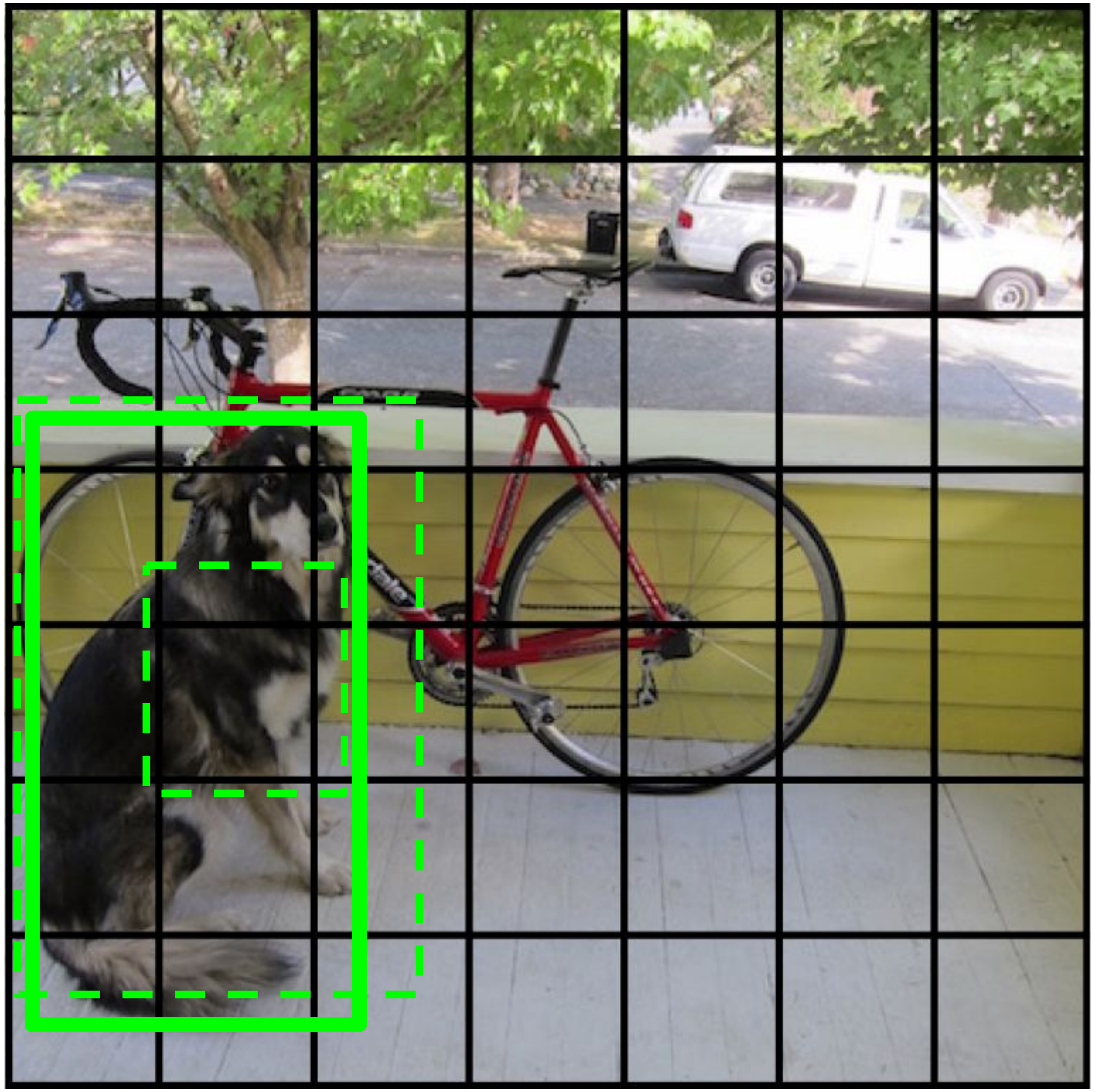
Dog = 1
Cat = 0
Bike = 0
...



Look at that cell's predicted boxes



Find the best one, adjust it, increase the confidence



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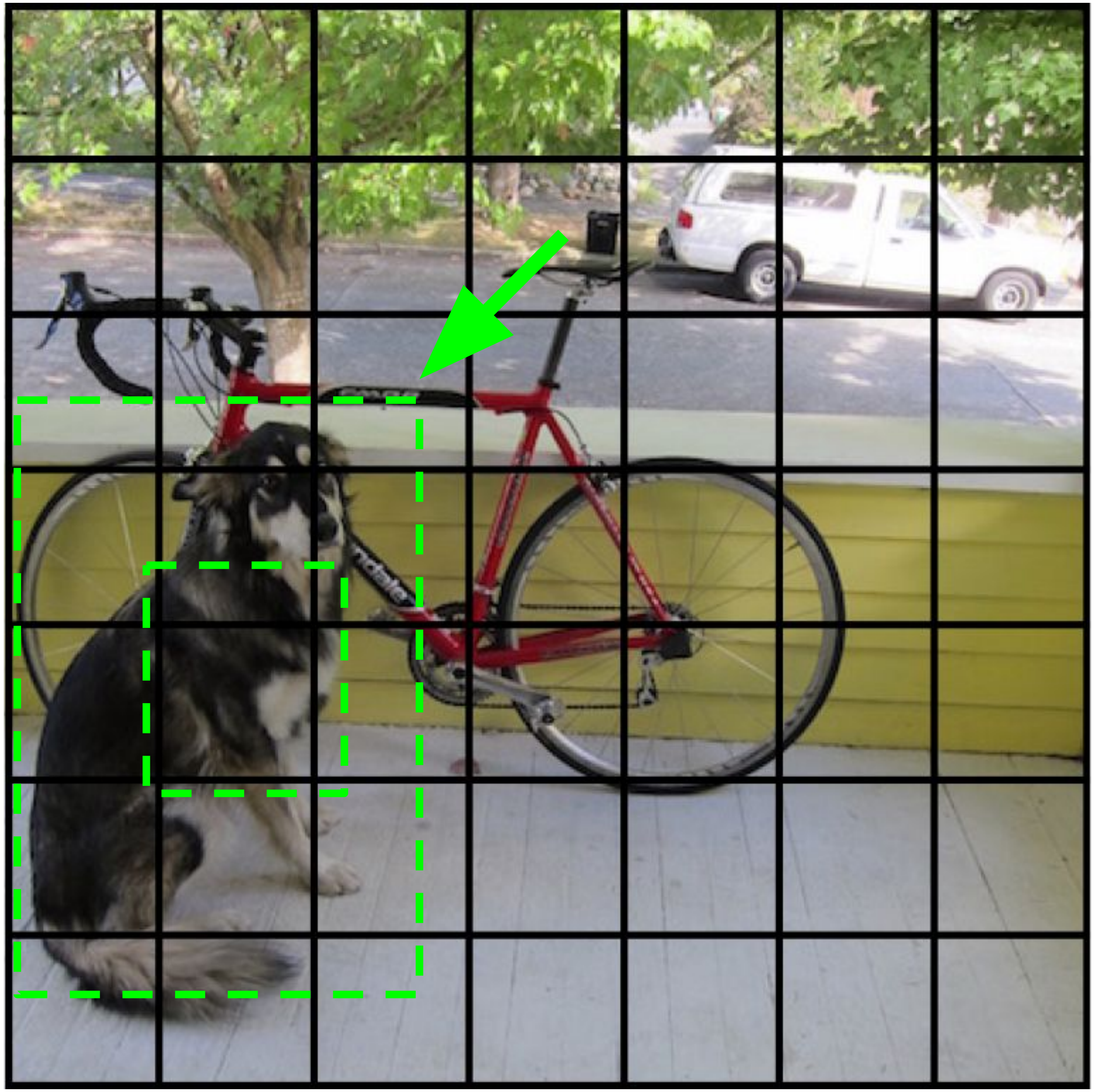

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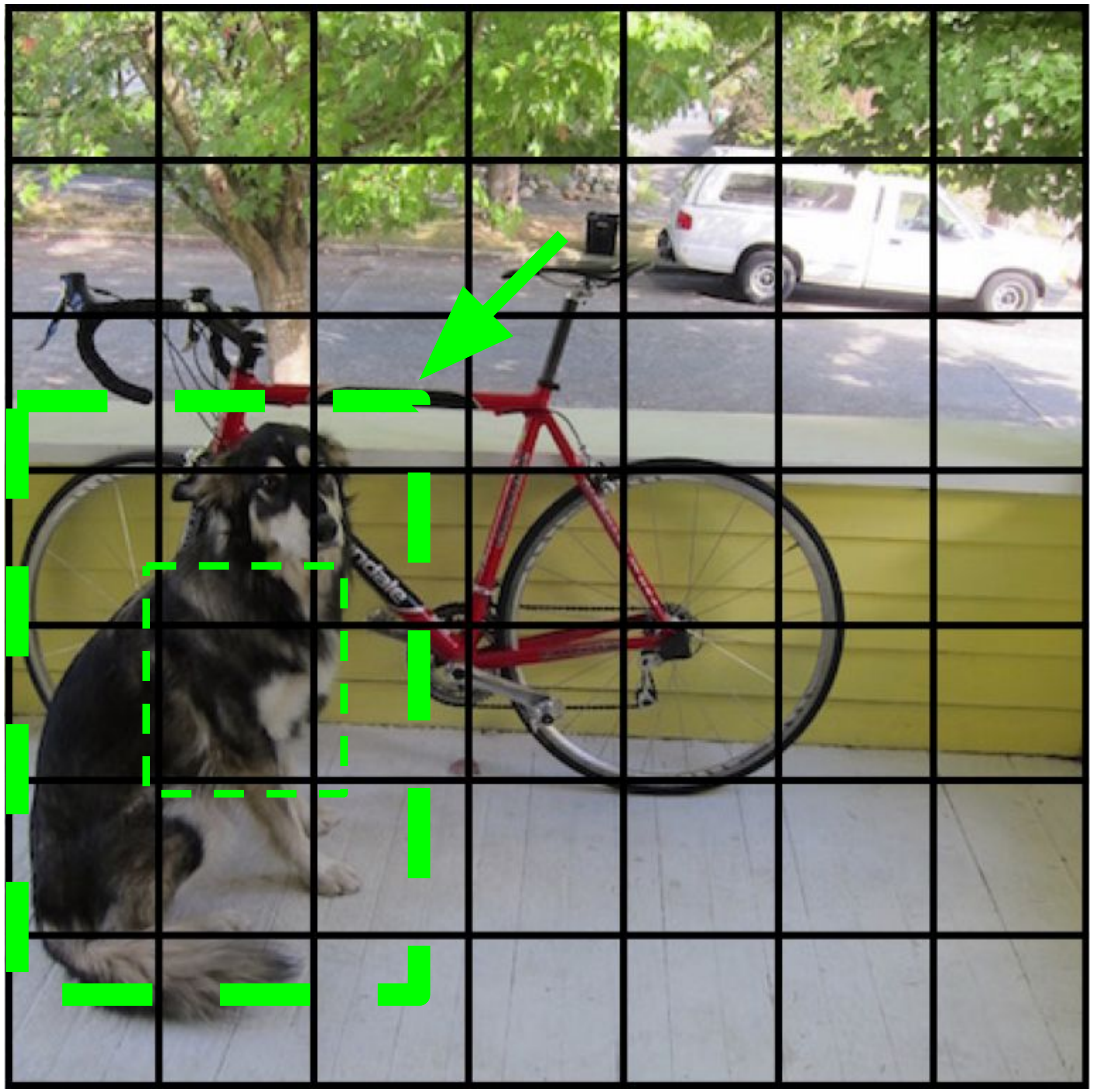
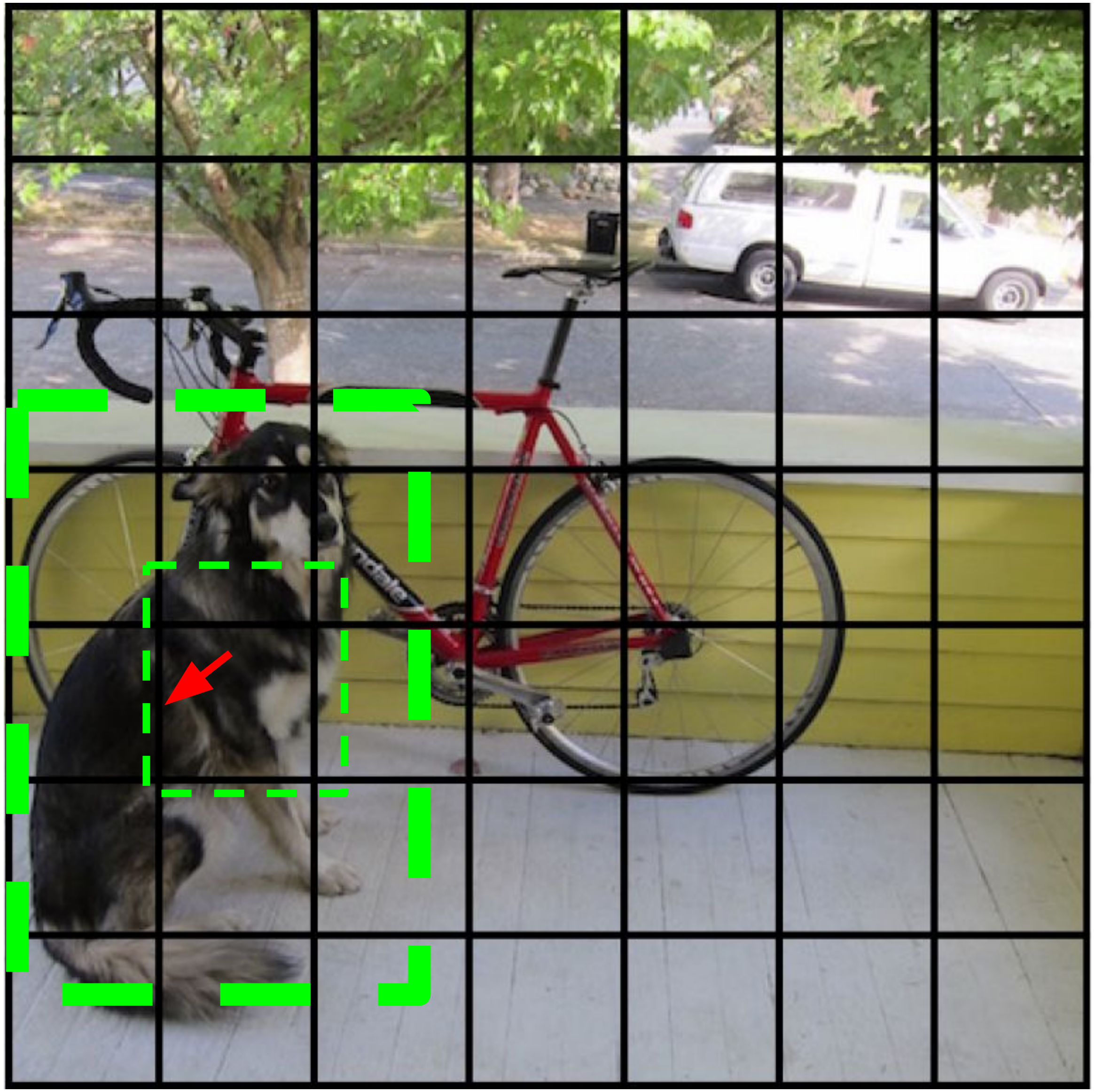


Decrease the confidence of other boxes



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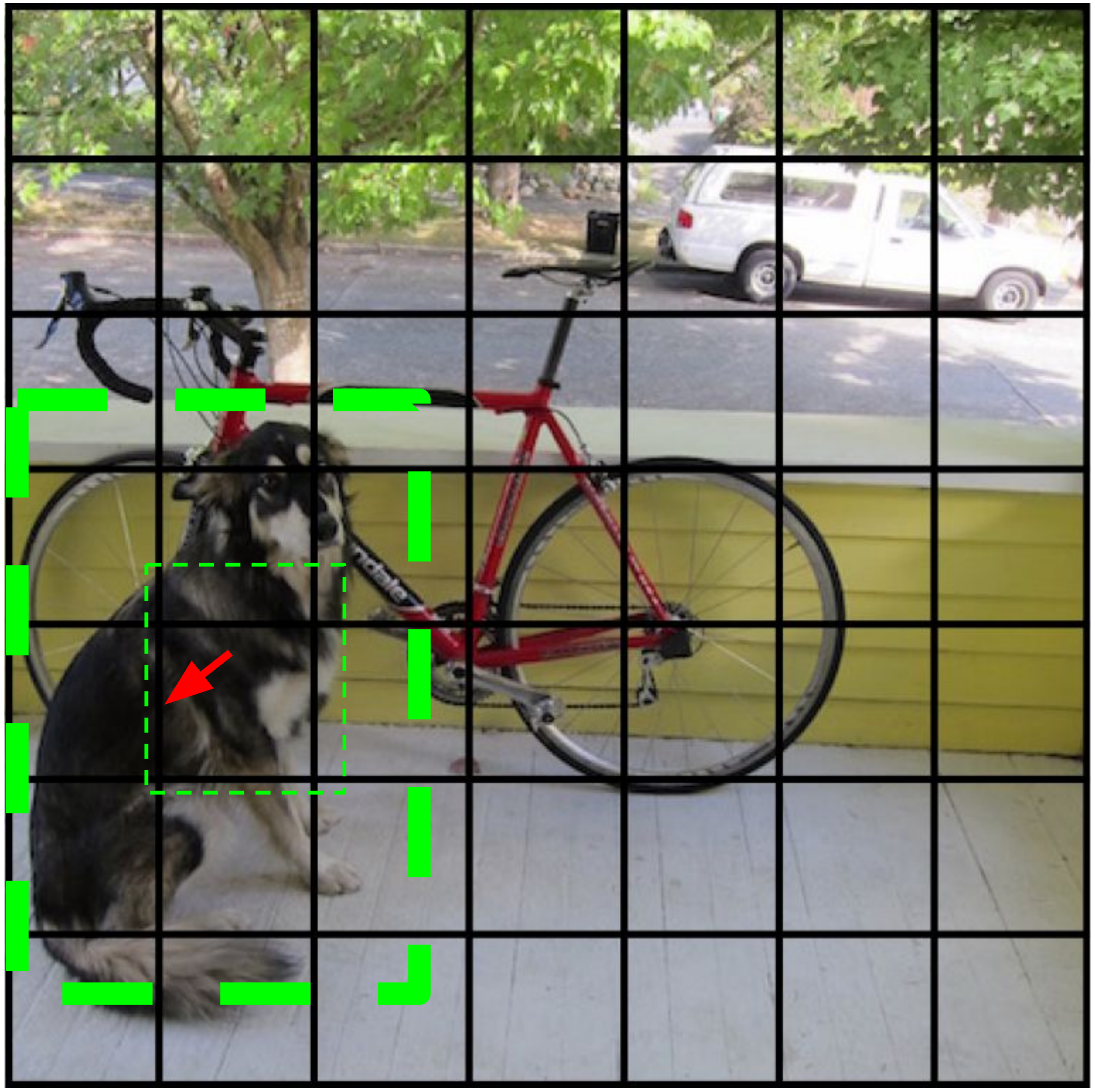
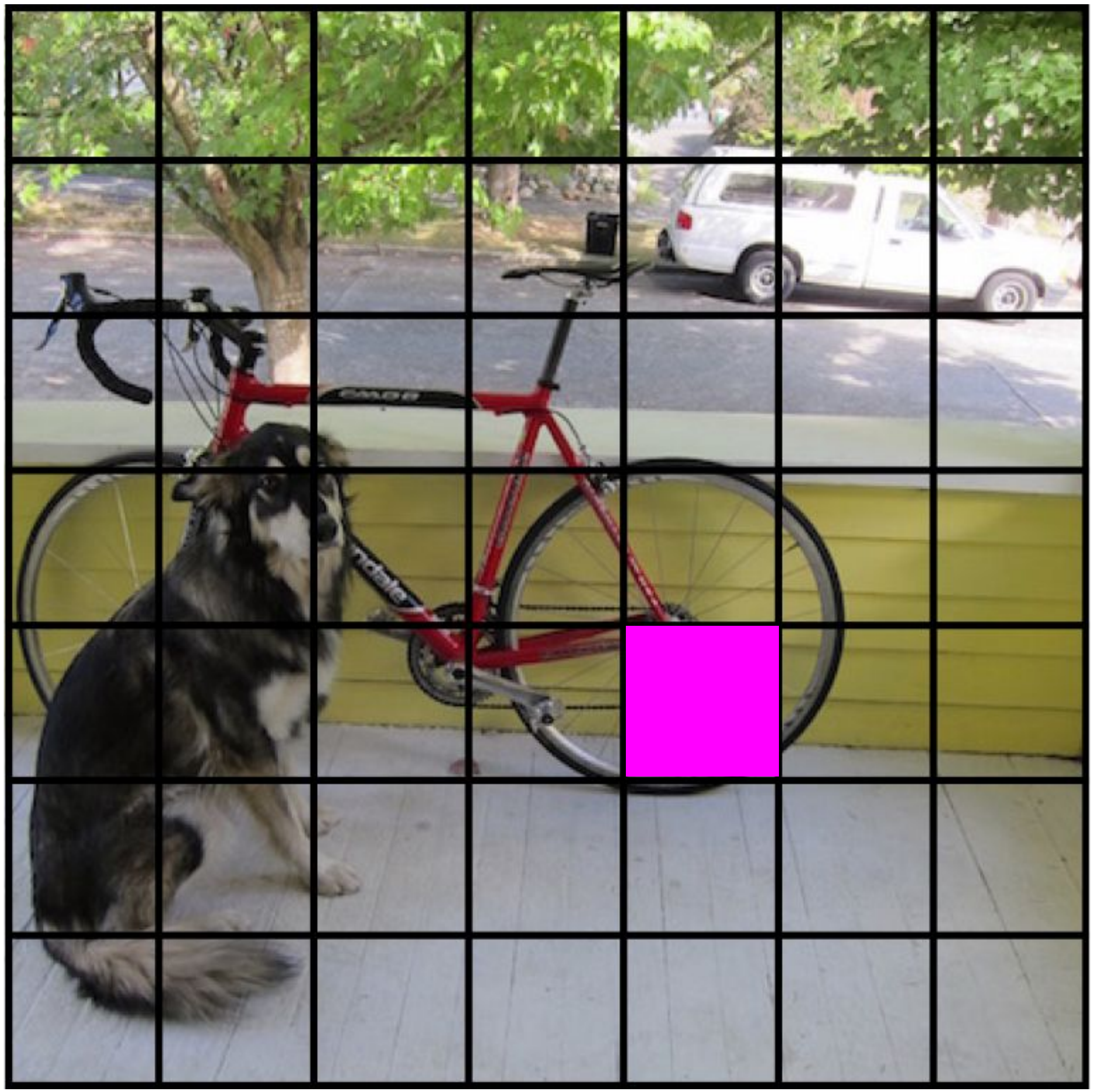


Some cells don't have any ground truth detections!



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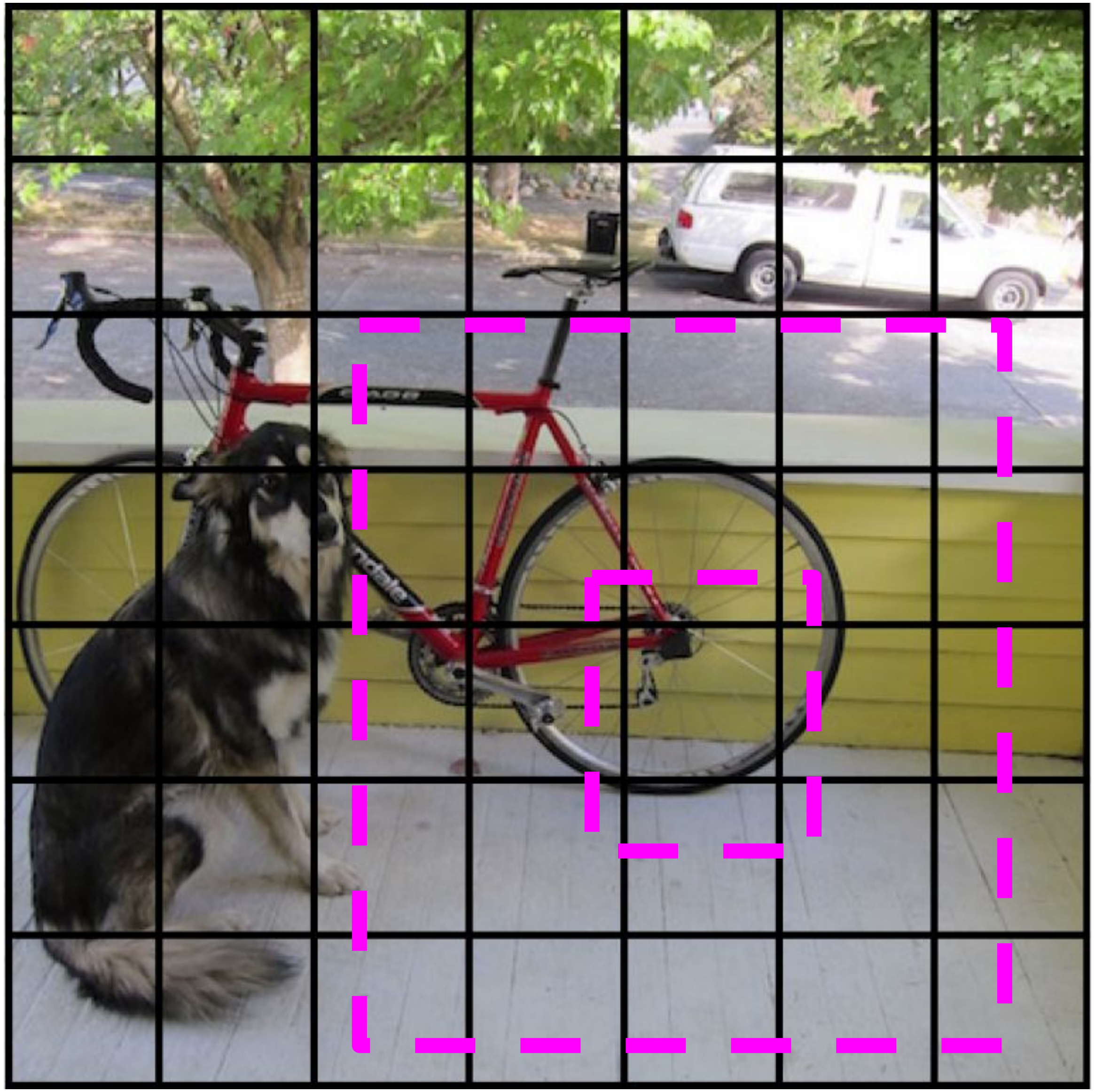
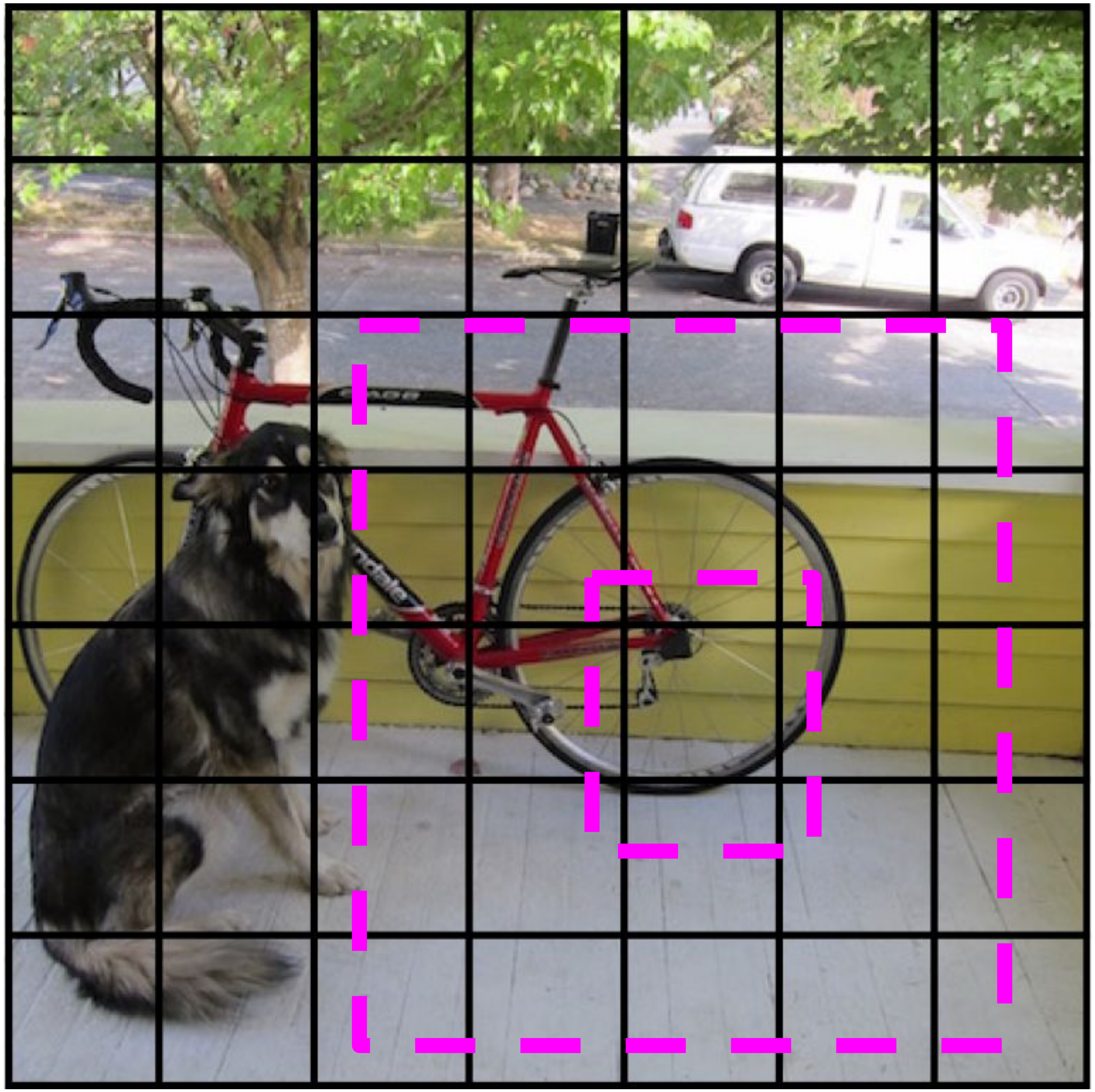


Decrease the confidence of these boxes



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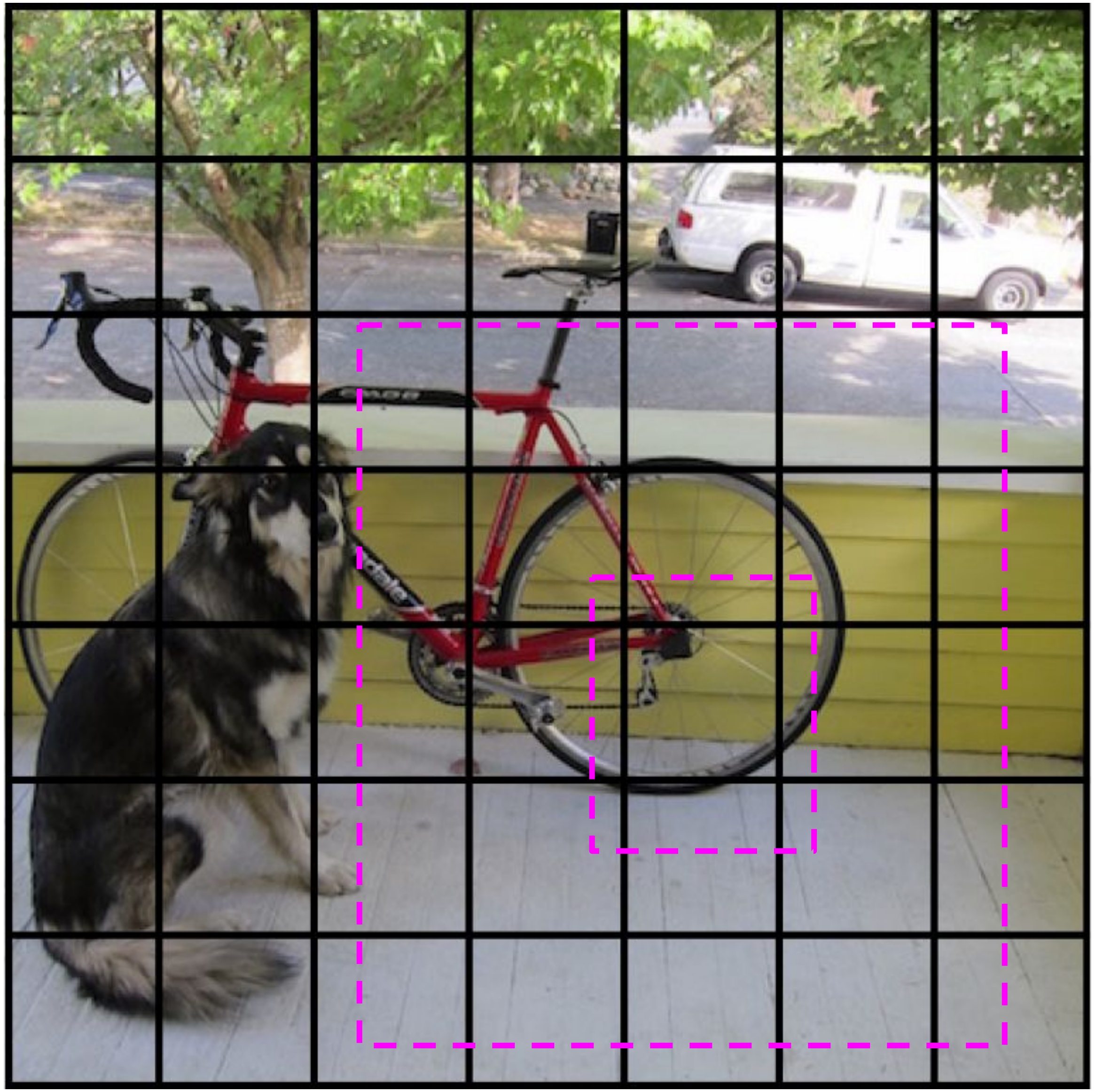
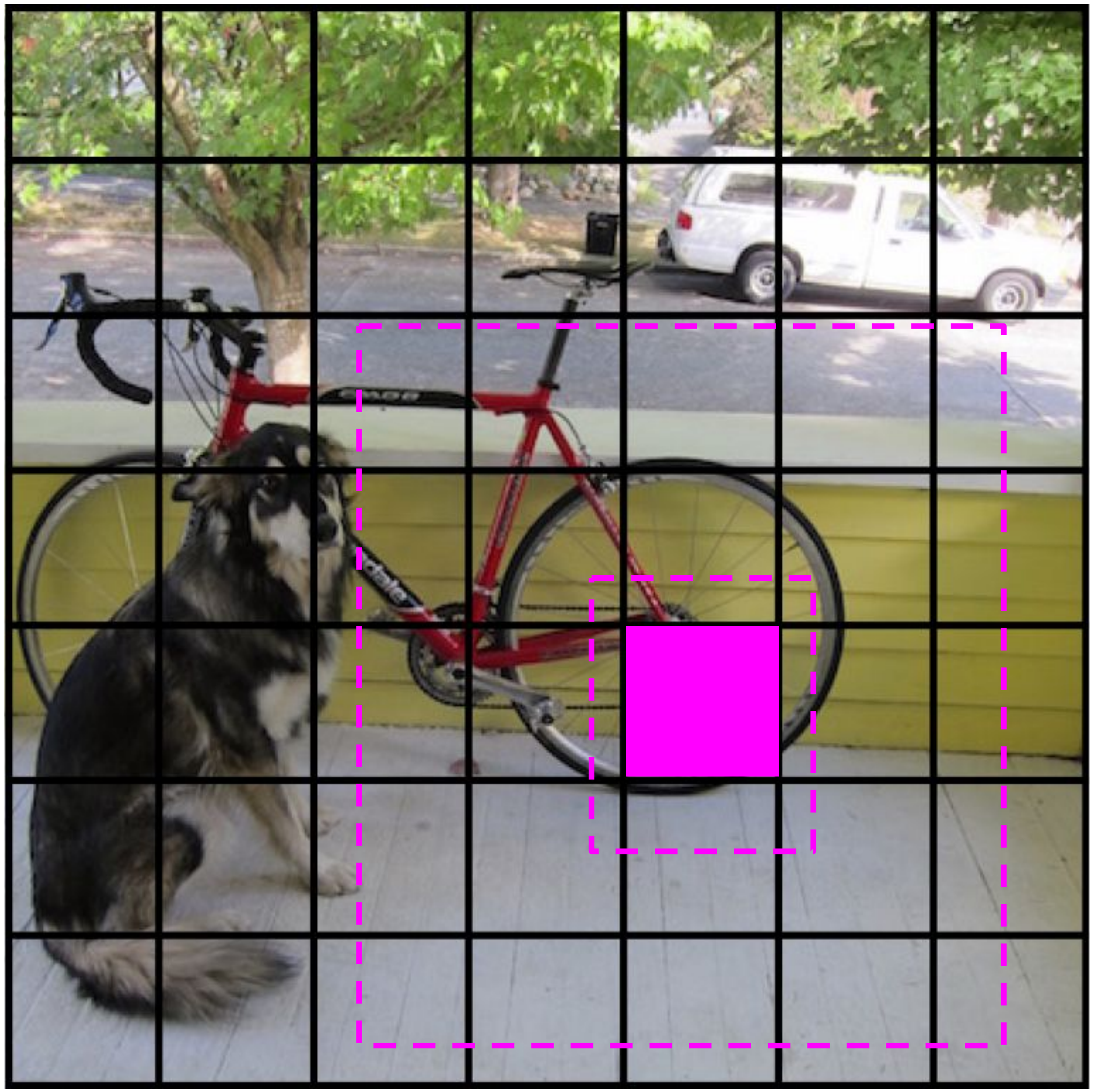
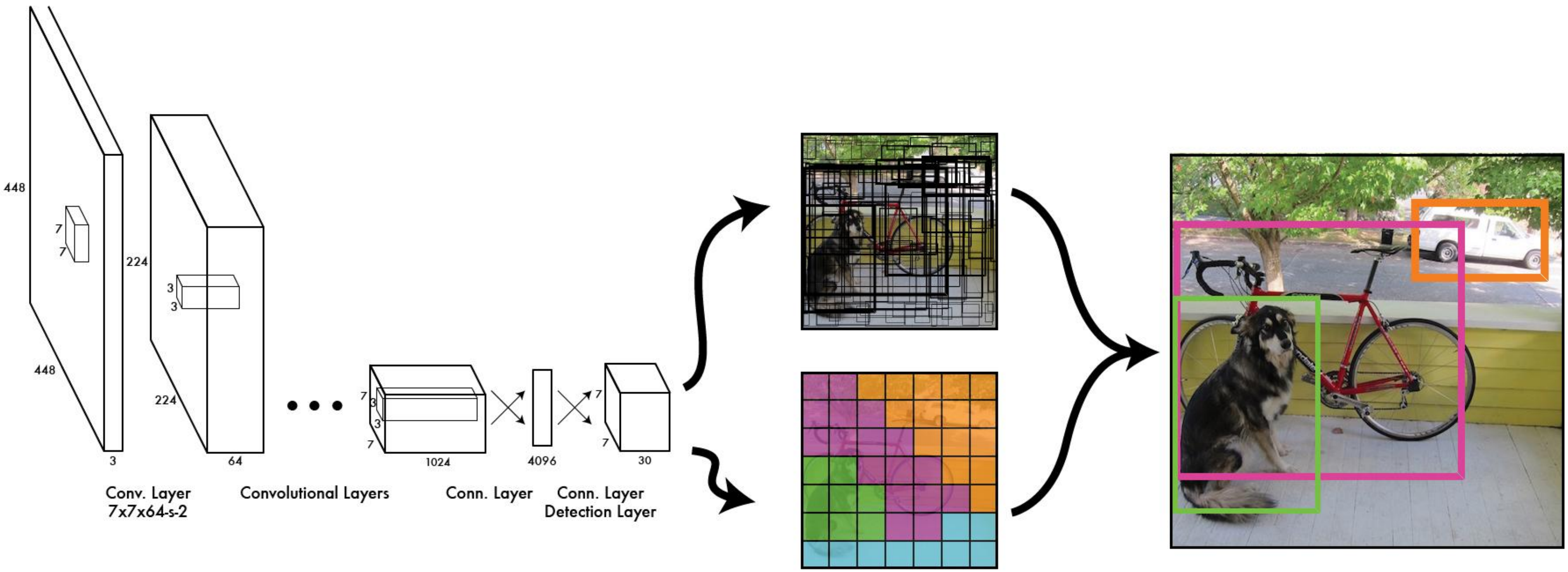


Don’t adjust the class probabilities or coordinates

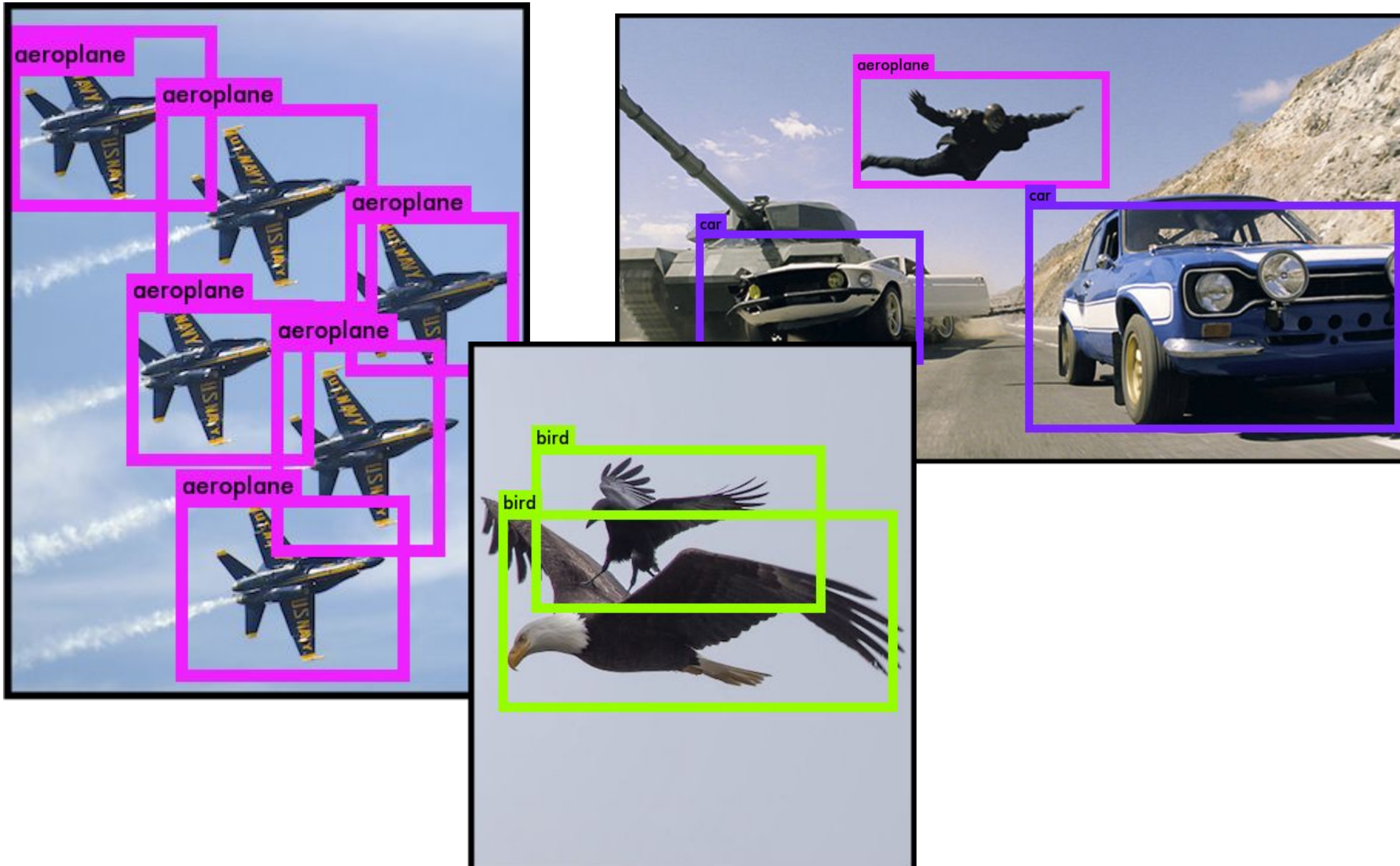


We train with standard tricks:

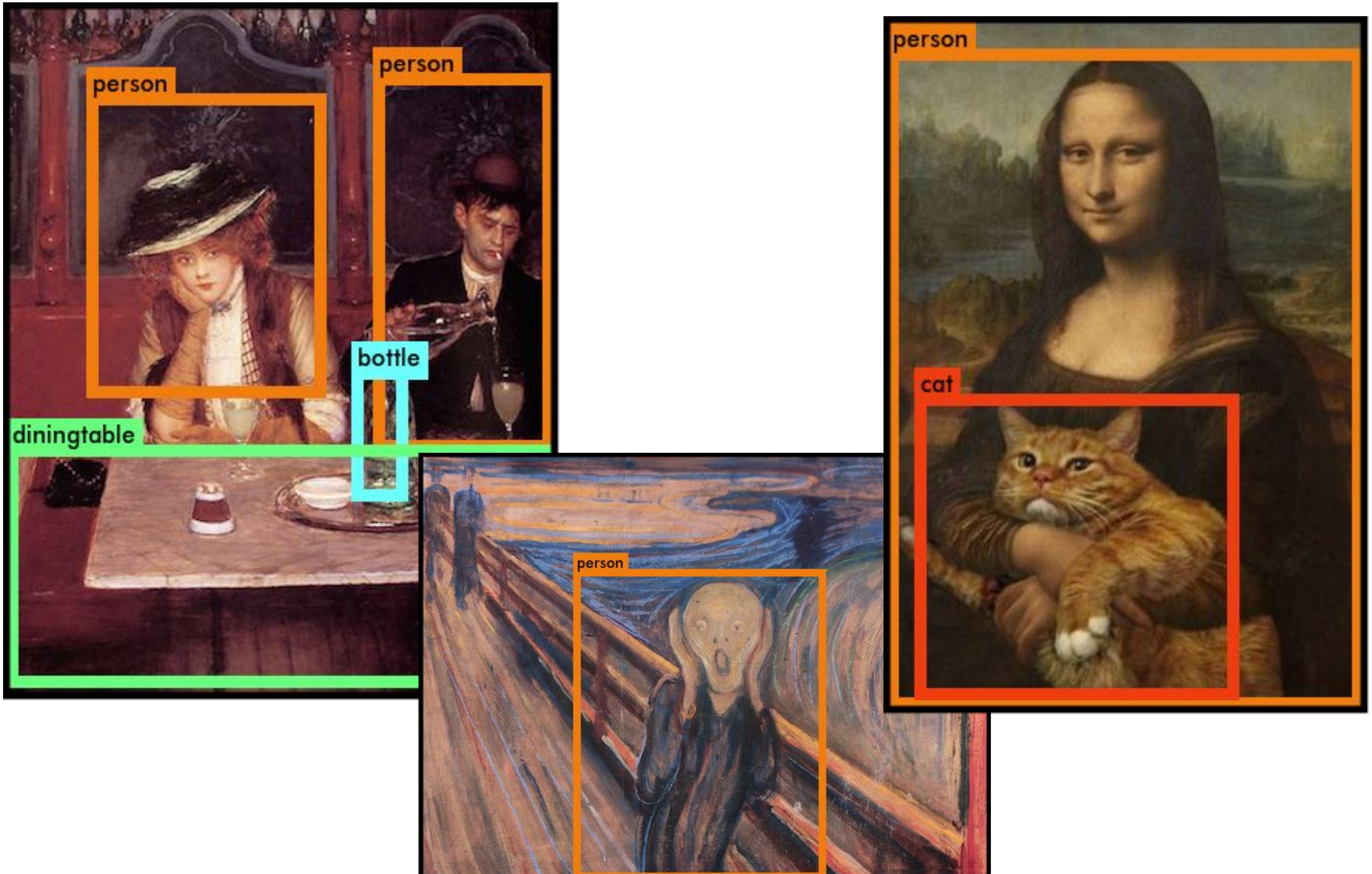
- Pretraining on Imagenet
- SGD with decreasing learning rate
- Extensive data augmentation
- For details, see the paper



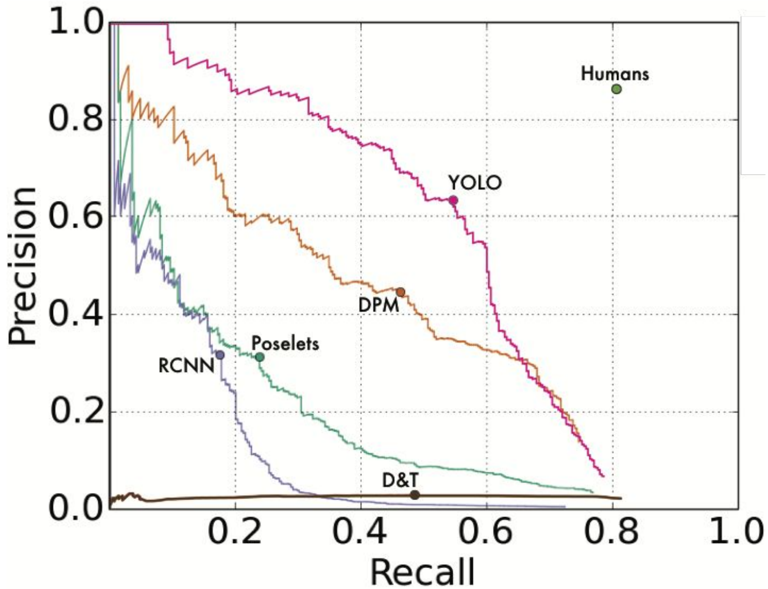
YOLO works across a variety of natural images



It also generalizes well to new domains (like art)



YOLO outperforms methods like DPM and R-CNN when generalizing to person detection in artwork



	VOC 2007	Picasso		People-Art
	AP	AP	Best F_1	AP
YOLO	**59.2**	**53.3**	**0.590**	**45**
R-CNN	54.2	10.4	0.226	26
DPM	43.2	37.8	0.458	32

S. Ginosar, D. Haas, T. Brown, and J. Malik. Detecting people in cubist art. In Computer Vision-ECCV 2014 Workshops, pages 101–116. Springer, 2014.

H. Cai, Q. Wu, T. Corradi, and P. Hall. The cross-depiction problem: Computer vision algorithms for recognising objects in artwork and in photographs.

Code available! pjreddie.com/yolo

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